https://doi.org/10.22319/rmcp.v13i1.5932

Article

Factors associated with indicators of calf rearing during the lactation period in small-scale dairy farms

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Abstract:

The objective was to evaluate the impact of factors associated with the management of the mother and the quality of colostrum on the calf rearing during lactation, in the small-scale milk production system. In 13 dairy farms, information was obtained on body growth, colostrum feeding and information associated with the mother of 220 Holstein calves. The variables of interest were: morbidity, concentration of immunoglobulins in colostrum (CIC; <110 mg/ml), serum protein concentration (SPC; <6.6 g/dL), daily weight gain (DWG; <0.650 kg/d) and daily height gain (DHG; <0.222 cm/d). The study factors were: body weight at birth (BWB; <42 kg), height at birth (HB; <82 cm), colostrum consumed on the first day (CCFD; <4 l), colostrum consumed on the first day/kg of LW (CFDLW), body condition at calving (BCC; <3), length of the dry period (LDP; >68 d), primiparous cows (PC) and cows without a challenge diet (CWCD). To determine the impact of the study factors on the events of interest, the odds ratio was obtained from multiple logistic regression analyses. The factors identified for morbidity were CCFD and PC (*P*<0.1). The factors for CIC were LDP and CWCD (*P*<0.1), while for DWG, it was CWCD (*P*<0.1). Finally, the factors for DHG were CWCD, BWB, HB and CFDLW (*P*<0.1). These results suggest that the mother's nutrition during late gestation has an important impact on the health and body development of calves during lactation. Further studies should determine long-term effects.

Key words: Colostrum, Calves, Morbidity, Growth.

Received: 29/01/2021

Accepted: 05/07/2021

Introduction

The most critical phase for the survival of a dairy calf occurs in its first weeks of life, and the events that occur in this period can affect its productive and reproductive performance in the future[1,2,3]. In highly technified and small-scale production systems, the highest morbidity and mortality rates in calves occur between birth and weaning, mainly due to problems of diarrhea and pneumonia[3,4,5]. Studies generated in the technified system report mortality and morbidity rates of up to 6 % and 38 %, respectively, during the lactation stage[6,7,8]. Some risk factors associated with this mortality and morbidity in calves are the low quality of colostrum[9], a late administration of colostrum[10], dystocia and body condition of the mother prior to calving[11], low weight at birth, a low concentration of IgG in serum, diseases during the period prior to weaning and a low consumption of fat in the liquid diet[12]. However, in the small-scale milk production system in Mexico, the production and management conditions are different from those of the technified systems; there is less efficiency in the rearing process[4], milk production levels are lower[13], nutritional management is poor[14] and reproductive performance is below optimal[15]. These differences allow questioning whether the risk factors reported in the technified system impact in the same way the indicators of rearing in the small-scale production system. The determination of these factors in this last system would allow implementing or design specific strategies for stables under this production system, in order to improve the rearing of calves. Therefore, the objective of this study was to identify factors associated with indicators of calf rearing in small-scale milk production systems. The working hypothesis is that there are individual risk factors of calves, mother and colostrum associated with the performance of calves during the lactation stage in this production system.

Material and methods

Location

The study was conducted in the Los Altos Sur region of Jalisco (20º 52’ N), in the municipalities of Valle de Guadalupe, San Ignacio Cerro Gordo and Tepatitlán de Morelos. In this region, there is a temperate subhumid climate, with an average annual temperature of 17.8 ºC and an average annual rainfall of 817 mm[16].

Information capture

During a nine-month period, information was obtained from 220 Holstein calves from 13 milk production farms with characteristics of the family system of the Los Altos region of Jalisco. The selection of stables was by a convenience sample with the following selection criteria: labor as the main operating support of the production unit, milk production as the primary target of the stable, a range between 10 and 100 cows in production and medium-low levels of technification. With these criteria, the farms met the characteristics of family stables in the region[17,18]. With the help of a veterinary zootechnician, with years of experience working in clinical practice in the region, and familiar from his participation in previous studies with the collection of samples, measurements and capture of necessary information, the calves were monitored from birth to weaning (71.6 ± 1.1 d), obtaining different growth indicators: weight at birth, weight at weaning, height at birth and height at weaning. From these values, the daily weight gain (DWG) at weaning and the daily height gain (DHG) at weaning were estimated. To estimate body weight, a tape measure specific to Holstein calves (Dairy Calf Tape, Coburn Co., Whitewater WI) was used, measuring their thoracic circumference behind the scapulae, while to record height at the withers, a somatometric ruler (Nasco, Whitewater WI) was used.

On the other hand, information was recorded on events associated with the calving of the mothers of the calves, length of the dry period, body condition at calving, number of calving and whether the mother received a challenge diet prior to calving (they received concentrate in the 2 to 3 wk prior to calving, regardless of its nutritional composition). To estimate the body condition at calving, a scale of 1 to 5 was considered, where a value of 1 corresponds to an animal in a state of wasting and a value of 5 to an obese animal[19].

Additionally, the following were recorded: the consumption of colostrum by the calf at the first intake and on the first day, the time elapsed from birth to the first intake of colostrum, the quality of colostrum (mg/ml) and the amount of serum protein (g/dL) in the calves at 48 h after birth. To determine the quality of the first postpartum colostrum, a sample of approximately 250 mL was collected and placed in a bain-marie at a temperature of 22 ºC; once this temperature was reached, the colostrum was deposited in a specimen and the amount of immunoglobulins present (mg/mL) was read by means of a colostrometer (Biogenics©, Mapleton OR). The concentration of total serum protein in the calf, as an indicator of passive immunity transfer failure, was determined in a blood sample obtained from the jugular vein at 48 h of birth; the sample was centrifuged at 2,500 rpm for 15 min and the serum obtained was kept in freezing (-20 ºC) until its analysis by refractometry. To do this, by means of a Pasteur pipette, a drop of the serum was taken, which was kept at room temperature (22 ºC) and deposited in the prism of a portable refractometer (Danoplus, Mod. RETK-70), with automatic temperature compensation and a reading range of 0-12 g/dL, trying to completely cover the surface and avoiding the formation of air bubbles that could distort the reading of the results. The refractometer was focused on a light source and the reading obtained was recorded. Prior to use, the refractometer was calibrated using distilled water and adjusting the calibrator screw, according to the manufacturer's instructions.

Events of interest

The selected events of interest were morbidity (sick calf at least once in the period from birth to weaning). The calves were monitored for signs of illness by the participating technician, as well as by information provided by the producer. Among the signs considered were lameness, difficulty moving, prostration, loss of appetite, dehydration, fever, cough, nasal or ocular discharges, lethargy and an abnormal consistency in the feces, without considering the length of these signs, nor their severity. Additionally, the remaining events of interest were the concentration of immunoglobulins in the first colostrum less than 110 mg/mL, serum protein concentration less than 6.6 g/dL, DWG less than 0.650 kg/d and DHG less than 0.222

cm/d. The limit values for the different events of interest were established based on the upper quartile of their distribution[15], except for daily weight gain at weaning.

Study factors

For the morbidity event, the factors considered were: colostrum consumed on the first day less than 4 l *vs* greater than or equal to 4 l, colostrum consumed/kg of live weight (LW) on the first day <0.105 *vs* >0.105 kg, body weight at birth less than 42 kg *vs* greater than or equal to 42 kg, height at birth less than 82 cm *vs* greater than or equal to 82 cm, body condition of the mother at calving less than 3 *vs* greater than or equal to 3, number of calving (first calving *vs* more than one calving) and offer of a challenge diet to the mother (NO *vs* YES). For the event serum protein concentration less than 6.6 g/dL, the factors analyzed were: colostrum consumed on the first day, colostrum consumed/kg of LW on the first day, weight at birth, height at birth, body condition of the mother at calving, number of calving, length of the dry period less than 68 d *vs* greater than or equal to 68 d and offer of a challenge diet to the mother. For the event DWG less than 0.650 kg/d and DHG <0.222 cm/d, the factors analyzed were: colostrum consumed on the first day, colostrum consumed/kg of LW on the first day, weight at birth, height at birth, body condition of the mother at calving, number of calving and offer of a challenge diet to the mother. The limit values for the different study factors were established based on the upper quartile of their distribution[15].

Statistical analysis

Statistical analyses were performed using the SAS 9.3 statistical package (SAS Institute Inc., Cary, NC). Initially, descriptive values for the variables considered in the study and their frequency were obtained. To build the multiple models, first, simple logistic regression models between each of the independent variables (study factors) and each event of interest were used, with the LOGISTIC procedure. Factors with significance $P \leq 0.35$ were keep to design the multiple models[20]. Subsequently, simple correlation analyses were performed between study factors to prevent collinearity in multiple models with the FREQ procedure. When the confidence limits of the correlation coefficients did not include 0 (indicating that there is a positive or negative association), both factors were not part of the same model. To obtain the models with the greatest parsimony, the backward option of the LOGISTIC procedure was used to eliminate from the model the study factors that were not significant at a value of $P > 0.1$[20]. Finally, the odds ratios (OR) were obtained from logistic regression analyses, as a measure of association between the events of interest and the study factors[21].

Results

Performance indicators

The weight and height of the calves at birth slightly exceeded 40 kg and 80 cm, respectively, with a daily weight gain at weaning of 503 g (Table 1). The liters of colostrum consumed in the first intake and the first day were 2.36 and 4.09, respectively, with more than 4 h, on average, elapsing to perform the first intake of colostrum. The immunoglobulin content in colostrum corresponded to a good quality, although with a wide range of values; the latter situation was similar to that observed in serum protein content and in the length of the dry period. Body condition at calving averaged 2.8.

Table 1: Descriptive statistics of variables associated with the rearing and peripartum management of Holstein cows

Variable	n	Average±SD	Minimum	Lower quartile	Upper quartile	Maximum
Body weight at birth, kg	207	40.39±2.99	29.00	39.00	42.00	52.00
Weight gain at weaning, kg/d	220	0.503±0.23	0.001	0.397	0.644	1.027
Height at birth, cm	207	80.28±3.38	66.00	78.00	82.00	89.00
Height gain at weaning, cm/d	220	0.168±0.08	0.002	0.122	0.222	0.351
Colostrum consumed in the first intake (l)	115	2.36±0.93	0.50	2.0	3.0	5.00
Colostrum consumed on the first day (l)	207	4.09±0.51	1.00	4.00	4.00	5.50
Colostrum consumed/kg LW, first intake (kg)	115	0.058±0.002	0.012	0.048	0.071	0.125
Colostrum consumed/kg LW, first day (kg)	213	0.102±0.00	0.026	0.095	0.105	0.139
Time to first intake of colostrum, h	119	4.24±3.31	0.35	2.0	6.0	18.00
Immunoglobulins in colostrum, mg/ml	133	81.56±33.74	10.00	85	110	165.00

Serum protein, g/dL	141	5.64±1.32	1.00	4.95	6.60	9.00
Body condition at calving	207	2.80±0.40	2.00	2.50	3.00	4.00
Length of the dry period, days	132	66.54±20.14	31.00	57	68	179.00
Number of calvings	215	1.71±0.45	1	1	2	9

SD= Standard deviation; LW= live weight.

Except for morbidity (29.9 %), the rest of the events had a prevalence of more than 70 % (Table 2). Fifty-three percent of the sick calves were associated with the occurrence of diarrhea, while 24.2 % were associated with respiratory problems suggestive of pneumonia and 22.7 % showed some other sign of illness or alteration. Of the factors under study, consumption of colostrum on the first day less than 4 L was the one with the lowest prevalence (4.3 %), while body weight at birth less than 42 kg, height at birth less than 82 cm, body condition at calving less than 3 and consumption of colostrum on the first day <105 kg/kg LW had prevalences greater than 60 %.

Table 2: Prevalences of events of interest and potential risk factors for calf rearing, included in logistic regression analyses

Variable	**%**
Events of interest:	
Morbidity	29.95
Concentration of immunoglobulins in colostrum <110 mg/mL	74.36
Serum protein concentration <6.6 g/dL	75.00
Weight gain at weaning <0.650 kg/d	74.88
Height gain at weaning <0.222 cm/d	74.40
Study factors:	
Body weight at birth <42 kg	69.08
Height at birth <82 cm	63.29
Consumption of colostrum on the first day <4 l	4.35
Colostrum consumed /kg LW, first day (kg)	65.70
Body condition at calving <3	63.29
Length of the dry period ≥68 d	26.92
First calving cows	28.99
Cows without a challenge diet	51.56

LW= live weight.

Association of study factors on events of interest

The simple logistic regression analyses (Table 3) show that for the morbidity event, the four study factors with a *P*<0.35 that were included in the multiple analyses were colostrum consumed on the first day (*P*=0.025), colostrum consumed on the first day per kg of live weight (*P*=0.174), number of calving (*P*=0.008) and challenge diet (*P*=0.223). For the event concentration of immunoglobulin less than 110 mg/ml, the only study factors considered were the length of the dry period (*P*=0.063) and the challenge diet (*P*=0.005). For serum protein concentration less than 6.6 g/dL, as an indicator of passive immunity transfer failure, the only factor considered was weight at birth (*P*=0.178). For weight gain at weaning less than 0.650 kg/day, three factors were considered, the number of calving (*P*=0.280), the challenge diet (*P*=0.004) and the colostrum consumed on the first day per kg of LW (*P*=0.340), while the factors colostrum consumed on the first day (*P*=0.329), colostrum consumed on the first day per kg of LW (*P*=0.004), weight at birth (*P*=0.067), height at birth (*P*=0.001), number of calving (*P*=0.105) and challenge diet (*P*=0.008) were considered for the event height gain at weaning less than 0.222 cm/d.

Table 3: Factors associated with some events. Analysis with simple models

Event of interest	**Risk factor**	***P* (OR)**
Morbidity	Colostrum consumed on the first day (<4 *vs* ≥4 l)	0.025 (5.071)
	Colostrum consumed/kg LW, first day (<0.105 *vs* ≥0.105)	0.174 (1.571)
	Number of calving (primiparous *vs* multiparous)	0.008 (2.358)
	Challenge diet (without diet *vs* with diet)	0.223 (0.675)
Immunoglobulin concentration <110 mg/ml	Length of the dry period (≥68 *vs* <68 days)	0.063 (4.385)
	Challenge diet (without diet *vs* with diet)	0.005 (5.665)
Serum protein concentration <6.6 g/dL	Weight at birth (<42 *vs* ≥42 kg)	0.178 (1.727)
Weight gain at weaning <0.650 kg/d	Number of calving (primiparous *vs* multiparous)	0.280 (1.495)
	Challenge diet (without diet *vs* with diet)	0.004 (0.372)
	Colostrum consumed/kg LW, first day (<0.105 *vs* ≥0.105)	0.340 (1.395)

Height gain at weaning <0.222 cm/d	Colostrum consumed on the first day (<4 *vs* ≥4 l)	0.329 (2.849)
	Colostrum consumed/kg LW, first day (<0.105 *vs* ≥0.105)	0.004 (0.385)
	Weight at birth (<42 *vs* ≥42 kg)	0.067 (0.499)
	Height at birth (<82 *vs* ≥82 cm)	0.001 (0.266)
	Number of calving (primiparous *vs* multiparous	0.105 (0.579)
	Challenge diet (without diet *vs* with diet)	0.008 (0.400)

P= probability value; OR= odds ratio; LW= live weight.

The significant effects of the multiple models for each event of interest, shown in Table 4, indicate that, for morbidity, the two factors that remained were colostrum consumption for a first model (*P*=0.023) and the number of calving for the second model (*P*=0.010). For the concentration of immunoglobulins less than 110 mg/ml, the factors that remained were the length of the dry period (*P*=0.062) and the challenge diet (*P*=0.005). For weight gain at weaning less than 0.650 kg/d, only the challenge diet remained (*P*=0.004). For the height gain at weaning less than 0.222 cm/d, the factors that remained in four models were the challenge diet for the first of them (*P*=0.008), weight at birth (*P*=0.055) and the challenge diet for the second (*P*=0.005), the height at birth (*P*=0.005) and the challenge diet (*P*=0.017) for the third model and the challenge diet and the consumption of colostrum on the first day/kg of LW (*P*=0.003).

Table 4: Non-collinear factors identified by multivariate analysis for some events

Variable	**Model**	**Factor**	**OR (95% CI)**	***P***
Morbidity	1	Consumption of colostrum on the first day		
		< 4 l	5.224 (1.257-21.711)	0.023
		> 4 l	Reference	
	2	Number of calving		
		Primiparous	2.395 (1.231-4.660)	0.010
		Multiparous	Reference	
Immunoglobulin concentration <110 mg/mL	1	Length of the dry period		
		≥ 68	0.214 (0.043-1.079)	0.062
		< 68	Reference	
		Challenge diet		
		Without diet	0.170 (0.049-0.588)	0.005
		With diet	Reference	

Weight gain at weaning <0.650 kg/d	1	Challenge diet Without diet With diet	 0.372 (0.187-0.736) Reference	 0.004
Height gain at weaning <0.222 cm/d	1	Challenge diet Without diet With diet	 0.400 (0.204-0.785) Reference	 0.008
	2	Weight at birth < 42 kg ≥ 42 kg Challenge diet Without diet With diet	 0.469 (0.216-1.017) Reference 0.377 (0.190-0.747) Reference	 0.055 0.005
	3	Height at birth < 82 cm ≥ 82 cm Challenge diet Without diet With diet	 0.253 (0.110-0.585) Reference 0.430 (0.214-0.860) Reference	 0.001 0.017
	4	Challenge diet Without diet With diet Colostrum consumed/kg LW on first day <0.105 ≥0.105	 0.368 (0.183-0.739) Reference 2.882 (1.449-5.735) Reference	 0.005 0.003

OR= odds ratio; CI= confidence interval; *P*= probability value.

Discussion

The average weight and height of calves at birth were similar to those described for this production system(4), although slightly lower than those published for calves from other systems(8,22,23). On the other hand, the average observed weight gain at weaning was lower than recommended(24) and showed results contrasting with that published by other authors(8,23,25). This could be due, at least in part, to the different management conditions of the farms, length of lactation periods and type of feeding (substitutes *vs* milk), among others.

The average consumption of colostrum in the first intake and the total of the first day were lower than that described by other authors[8,23]. Even considering the consumption of colostrum per kilo of live weight in the first intake, it was not possible to cover the 10 to 12 % recommended for the first hours[26], achieving it only after the first day. A high percentage of calves consumed less than 4 L of colostrum on the first day, while the time elapsed to the first intake of colostrum is greater than that recorded in other studies[8,27]. Despite the deficiencies observed in the consumption of colostrum, it seems that the protection achieved by calves, measured in total serum protein, was adequate[27], perhaps as a result of the high quality of the colostrum offered[24], which is higher than that observed in herds of a larger size and technification[23]. In the latter, it has been described that only 23 % of colostrum meet quality standards[9]. It is likely that the lower milk productions of cows in the small-scale system[13] will allow the concentration of immunoglobulins in colostrum to be higher by avoiding their dilution[28]. Thus, although the first intake of colostrum in calves under the small-scale milk production system could be lower than suggested[26], its quality would guarantee effective protection. However, the wide variation in results observed in both the concentration of immunoglobulins in colostrum and the amount of serum protein should be considered.

The low body condition of the cows at calving and the high percentage that had with less than 3 points of body condition may be the result of poor feeding conditions that exist in the herds[14,15,29], which is reflected in the low percentage of cows that received a challenge diet.

For the morbidity event, the multiple analysis indicated that those calves that consumed less than 4 L of colostrum on the first day were 5.2 times more likely to get sick compared to those that consumed higher amounts. In this way, this should be taken into consideration, even if the average total serum protein readings show good results. Additionally, the greater probability of getting sick in calves that were daughters of first calving mothers *vs* multiparous mothers, similar to that described by other authors[30], may be due to the fact that the colostrum of the former contains less immunoglobulins or its quality may be lower than that of cows with a greater number of calvings[31,32,33]. Due to the high morbidity rates recorded for this small-scale system, special attention should be paid to the feeding offered to the calf on the first day and the best housing conditions should be sought, especially when the calves come from first calving mothers.

Considering that a low consumption of colostrum could put the health of a calf at risk, ensuring its quality is also a priority. Not consuming a challenge diet decreased the likelihood of having a colostrum of lower quality (<110 mg/ml), thus showing a protective effect. Although the offer of concentrate prior to calving, which coincides with the formation of colostrum[26], could favor a greater initial production, this could cause a dilution in the content of immunoglobulins. This is somewhat similar to what has been observed in the sheep species[34], where restricted sheep had a lower volume of colostrum, but a higher content of immunoglobulins, compared to sheep consuming 100 % of their nutritional requirements. However, no differences in colostrum quality have been observed due to the consumption of concentrate or higher consumption of metabolizable energy prior to cow calving[35,36]. The second factor associated with the concentration of immunoglobulins that remained in the multivariate analysis was the dry period; at a longer length of this period, the probability of a low concentration of immunoglobulins in colostrum decreased, compared to periods of less than 68 d. There is little comparable information available; although it has been described that a dry period of 40 days in cows showed no difference in the concentration of immunoglobulins in colostrum, compared to 60 d[37]. It is likely that a longer dry period, which reached up to 179 days for the animals in this study, allows their greater body recovery and this favors the concentration of immunoglobulins in colostrum; this should be analyzed in subsequent studies.

Not offering a challenge diet to the mother decreased the likelihood that the calf would have low weight and height gain at weaning (i.e., it had a protective effect). In this regard, no differences were observed in the weight or weight gain of calves whose mothers received or not concentrate, prior to calving[35]. A limitation of this study is not having recorded the amount and nutritional composition of the challenge diet offered to the cows, which could give greater guidance on the results obtained. Some nutritional alterations during the *in-utero* life of the calves could affect their performance from birth[38], so it is likely that less nutrition of the cow during the final phase of gestation causes compensatory mechanisms in the calf that favor its initial growth after birth, as has been observed in other phases of growth[39]. Only a few studies have described the favorable effects that nutrition in late gestation can have on the growth of calves[40], which may be partly due to the fact that most studies are generally limited to obtaining indicators in the calves at birth[41], without evaluating their subsequent performance. Additionally, it was observed in one of the models that consuming colostrum in an amount less than 0.105 kg/kg of LW on the first day increased almost 3 times the risk of having a lower growth in the calves. It is likely that components of colostrum, such as hormones, growth factors and nutrients, which may be in greater quantity in the first colostrum, favor the growth of calves[26]. Unfortunately, height and its gain at weaning are not included in studies as often as body weight. Although there is a greater weight gain at weaning in calves with a higher consumption of colostrum[42], in another study, the same was not observed for height at weaning[43]. However, the design considered the use of colostrum of good quality and in appropriate quantities, even for the group with the lowest consumption of colostrum (10 *vs* 15 and 20 % of body weight), which may decrease the possibility of observing differences between groups.

Conclusions and implications

In conclusion, the factors associated with the rearing of calves identified were colostrum consumed on the first day, primiparous cows, length of the dry period, cows without a challenge diet, body weight at birth and height at birth. The factor with the greatest impact on the performance of calves during lactation was cows without a challenge diet, for positively impacting the events of interest concentration of immunoglobulins in colostrum, daily weight gain and daily height gain at weaning. This result is interesting because of the possible practical implications that could arise, for example, recommending not to provide a challenge diet to cows under this production system. However, complementary studies are needed to analyze the long-term effect on calf performance beyond the lactation stage and the productive and health impacts of the mother.

Acknowledgements

Study financed with fiscal funds allocated to the project SIGI 23335132549 entitled "Nutritional supplementation in critical periods of calf breeding, to improve their productive performance in family/semitechnified milk production systems" of the National Institute of Forestry, Agricultural and Livestock Research.

Conflict of interest

The authors declare that they do not have no financial or personal conflict of interest associated with this study.

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