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Impact of Management Practices on Calf Mortality Rates in Dairy Farms: A Study in the Gaziantep Region of Türkiye

ABSTRACT

Objective: This study assesses calf-rearing practices and their effects on calf mortality in the TRC1 region of Southeastern Anatolia, Türkiye. By classifying farms into low, medium, and high mortality groups, it identifies key factors impacting calf survival and offers insights to enhance calf health, reduce mortality, and improve dairy farm sustainability.

Material and Methods: The study was conducted in Türkiye's TRC1 region, home to around 388,000 dairy cattle. Data were collected from 145 dairy farms during the 2019–2020 period using stratified random sampling. Farms were grouped by mortality rate using K-means clustering. Statistical tests (ANOVA, Kruskal-Wallis, t-test, Mann-Whitney U test) and multiple regression analysis assessed factors such as colostrum intake, milk feeding frequency, and weaning age on calf mortality.

Results: Significant variability in calf-rearing practices was observed. The average colostrum intake was 2.64 liters initially and 3.15 liters for the second feeding, with wide ranges. Milk was fed 2.08 times per day, and weaning ages spanned 30-180 days. Low-mortality farms had higher colostrum intake and consistent feeding schedules. Regression analysis identified colostrum intake, milk feeding frequency, and weaning age as significant calf mortality predictors.

Conclusion: The study underscores the importance of early calf management on mortality rates. Improved colostrum intake, feeding frequency, and appropriate weaning age can enhance calf survival and farm profitability, offering valuable guidance for dairy farmers.

Keywords: Calf feeding practices, calf health, calf mortality, colostrum intake, dairy farm management, farm sustainability.

Yönetim Uygulamalarının Süt Çiftliklerinde Buzağı Ölüm Oranları Üzerindeki Etkisi: Türkiye'nin Gaziantep Bölgesinde Bir Çalısma

ÖZ

Amaç: Bu çalışma, Türkiye'nin Güneydoğu Anadolu Bölgesi olan TRC1 bölgesinde buzağı yetiştirme uygulamalarını ve bunların buzağı ölümleri üzerine etkilerini değerlendirmektedir. Bu çalışma çiftlikleri düşük, orta ve yüksek ölüm oranlarına göre sınıflandırarak buzağıların hayatta kalmasını etkileyen temel faktörleri tanımlamakta ayrıca buzağı sağlığını iyileştirmeye, ölümleri azaltmaya ve süt çiftliği sürdürülebilirliğini geliştirmeye yönelik bilgiler sunmaktadır.

Materyal ve Metot: Araştırma, Türkiye'nin yaklaşık 388.000 süt sığırına ev sahipliği yapan TRC1 bölgesinde gerçekleştirilmiştir. Veriler 2019-2020 üretim döneminde 145 süt çiftliğinden tabakalı tesadüfi örnekleme yöntemi ile toplanmıştır. Örneklenen çiftlikler, K-ortalama kümeleme yöntemi kullanılarak ölüm oranlarına göre grublandırılmıştır. İstatistiksel testler (ANOVA, Kruskal-Wallis, t-testi, Mann-Whitney U testi) ve çoklu regresyon analizi ile kolostrum alımı, süt besleme sıklığı ve sütten kesim yaşı gibi buzağı ölümleri üzerine etkili faktörler değerlendirilmiştir.

Bulgular: Buzağı yetiştirme uygulamalarında önemli farklılıklar gözlenmiştir. Ortalama ilk kolostrum alımı 2,64 litre, ikinci beslemede ise geniş aralıklarda 3,15 litre olarak gerçekleşmiştir. Günde 2,08 kez süt beslemesi yapılmış ve sütten kesim yaşları 30-180 gün arasında olduğu tespit edilmiştir. Ölüm oranının düşük olduğu çiftliklerde daha yüksek kolostrum alımı ve tutarlı beslenme programları gerçekleştirilmiştir. Regresyon analizi ile kolostrum alımını, süt besleme sıklığını ve sütten kesme yaşının buzağı ölümlerinin önemli belirleyicileri olduğu tespit edilmiştir.

Sonuç: Bu çalışma buzağılarda erken dönem yönetim uygulamalarının ölüm oranları üzerindeki önemini vurgulamaktadır. Kolostrum alımının iyileştirilmesi, süt besleme sıklığı ve uygun sütten kesme yaşının tespiti buzağıların hayatta kalmasını ve çiftliklerin kârlılığını arttırarak hayvancılık işletmelerine değerli bir katkı sağlayacaktır.

Anahtar Kelime: Buzağı besleme uygulamaları, buzağı sağlığı, buzağı ölümü, kolostrum alımı, süt çiftliği yönetimi, çiftlik sürdürülebilirliği

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INTRODUCTION

Calf mortality presents a significant challenge for dairy farmers, directly influencing herd productivity, profitability, and the future health of the farm. The early life stages of a calf are especially critical; mortality during this period results in immediate economic losses and compromises long-term herd performance, as calves represent the next generation of cattle whose successful development is essential for the farm's sustainability (Avcioğlu et al., 2024; Hoischen-Taubner et al., 2021; Lancaster & Larson, 2022; Lovarelli et al., 2020; Pulina et al., 2021). Key management practices—such as ensuring adequate colostrum intake, optimizing milk feeding frequency, determining the right weaning age, and providing consistent access to clean water and starter—play pivotal roles in improving calf survival and promoting healthy growth (Lorenz, 2021; Machado & Ballou, 2022; Shiasi Sardoabi et al., 2021). Effective early-life interventions, including precise feeding protocols and environmental management, are vital in reducing mortality rates and enhancing overall farm efficiency (Hyde et al., 2022; Lancaster & Larson, 2022; Machado & Ballou, 2022). Understanding the impact of these practices during the vulnerable calf-rearing phase is crucial for improving the economic viability and resilience of dairy farming operations. Previous studies have highlighted the importance of factors like colostrum management, feeding routines, and housing conditions in reducing calf mortality (Barry et al., 2020; Johnsen et al., 2021; Machado & Ballou, 2022); however, there remains a need to systematically analyse how these variables contribute to mortality outcomes across different farm settings. By identifying management practices associated with high, medium or low mortality rates, dairy farmers can adopt evidence-based interventions to reduce losses and improve herd performance.

Considering the food crisis that began due to COVID-19 and has continued to escalate recently (Khan et al., 2020; Rahimi et al., 2022), calf losses on farms pose a significant risk worldwide (Hashem et al., 2020). In terms of feeding, treatment, and labor costs in calf rearing, each calf lost incurs substantial damage to the economy (Dubrovsky et al., 2020; Han et al., 2020). However, calf losses also have serious implications for the sustainability of farms and the dairy industry (Avcioğlu et al., 2024; Hoischen-Taubner et al., 2021; Vaarst et al., 2020). Calf losses are most commonly observed during the milk-feeding period (Machado & Ballou, 2022; Schild et al., 2020). Therefore, management practices related to calf care, feeding management, colostrum management, and the prevention of digestive and respiratory diseases are crucial (Lorenz, 2021; Machado & Ballou, 2022; Shiasi Sardoabi et al., 2021). Studies on calf rearing demonstrate that management practices significantly impact calf losses (Hayer et al., 2021; Kantwa et al., 2023). A recent study indicated that 54% of animals that died in the United Kingdom over seven years were less than 24 months of age. Moreover, calves under the age of three months accounted for 25% of the total death rate in the country (Hyde et al., 2020). Additionally, research conducted in Türkiye found the calf mortality rate on a specific farm to be 13.3% (Küçükoflaz & Sarıözkan, 2023). However, for calves aged 2 to 3 months, the acceptable mortality rate should not exceed 2% (Cornell, 2003). These losses clearly highlight the impact of management practices on calf rearing.

Another study investigated the effect of the time between birth and the first colostrum given on mortality rates. It reported that administering colostrum to calves immediately after birth significantly reduced mortality (Barry et al., 2019). Additionally, the amount of colostrum given right after birth has a significant effect on mortality rates (Lombard et al., 2020). A study on daily milk allowance in calves reported that feeding frequency, as a management practice, was not significant (Jensen et al., 2020). In another study conducted in Portugal, calf losses due to diarrhea, respiratory problems, and sudden death were reported at 78.8%, 60.7%, and 82.1%, respectively (Santos et al., 2019). One contributing factor to calf deaths from diarrhea during the milk-feeding period is the temperature of the milk provided (Schinwald et al., 2022). Ultimately, calves in dairy farms directly affect sustainability and profitability and constitute the future of the farm (Avcioğlu et al., 2024; Hoischen-Taubner et al., 2021; Lancaster & Larson, 2022; Lovarelli et al., 2020; Pulina et al., 2021). The accuracy of management practices in calf rearing minimizes mortality and enables calves to become healthy and highly productive animals in the future (Schnyder et al., 2019). This study aimed to investigate the impact of various calf-rearing practices on calf mortality rates. Through a robust methodological approach, the research classified farms into low, medium, and high mortality rate groups, allowing for a comprehensive comparison of management practices across the Gaziantep region (TRC1) of Turkiye. By identifying the critical factors contributing to calf mortality, this study offers actionable insights that can improve calf health, reduce mortality, and enhance overall dairy farm efficiency. The findings provide valuable guidance for producers seeking to optimize their calf-rearing strategies and strengthen the long-term sustainability of their operations.

MATERIAL and METHODS

The research was carried out in the TRC1 region, which is recognized as the largest agricultural production zone in Southeastern Anatolia, Türkiye (Figures 1 and 2). This region is home to approximately 388,000 cattle, representing about 3% of the total dairy cattle population in Türkiye (TUİK, 2020). Data for the study were gathered through surveys conducted during the 2019-2020 production cycle. Additionally, information from prior research and records obtained from various institutions and organizations was incorporated. The study's methodologies are divided into three main categories: (i) data collection for research, (ii) classification of calf mortality rates across dairy farms, and (iii) statistical analyses.

Figure 1: Location of the research area within Türkiye and in a global context

Figure 1: Araştırma alanının Türkiye ve küresel ölçekteki konumu

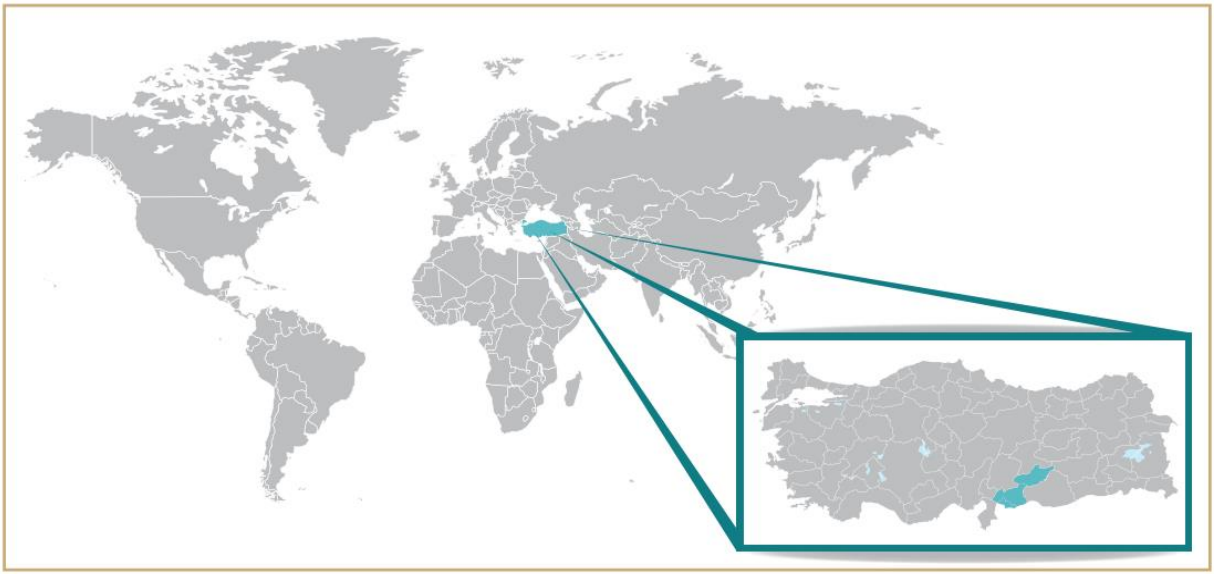

Figure 2: Map of the research area (Gaziantep, Kilis, and Adıyaman).

Figure 2: Araştırma alanının haritası (Gaziantep, Kilis ve Adıyaman).

Collecting Research Data

A stratified random sampling technique, known as the Neyman method, was employed to determine the number of dairy farms to be surveyed in the study area. The selection of farms was based on the number of animals owned, which served as the primary sampling criterion. Initially, a total of 791 farms were identified as the sampling frame. To ensure statistical reliability, the sampling process adhered to a 5% margin of error and a 99% confidence level. Further details about the surveyed farms can be found in Tables 1 and 2.

Table 1. Stratified allocation of dairy farms for the survey.

Tablo 1. *Anket için süt çiftliklerinin tabakalı dağılımı*

Stratums (Animal no)	Population	Mean	Standard Error	Sample Size
First stratum (01 - 30)	370	23.69	2.87	68
Second stratum (31 - 100)	307	47.06	17.30	56
Second stratum (101 – 101+)	114	305.18	219.11	21
Total	791	73.33	127.15	145

Based on the sampling formula provided by Yamane (2001), it was determined that 145 dairy farms should be surveyed:

$$n = \frac{\left(\sum N_h S_h\right)^2}{N^2 D^2 + \sum N_h S_h^2}$$

In this equation, n represents the number of farms to be surveyed, N stands for the total population of farms, N_h is the number of farms in each stratum, S_h denotes the standard deviation within each stratum, and D indicates the allowable margin of error.

To allocate the sample size proportionally across strata, the standard deviation of each stratum was used as the basis, calculated as follows:

$$n_h = \frac{N_h S_h}{\sum N_h S_h} \times n$$

In this formula, n refers to the optimal sample size, N_h represents the number of samples within stratum h, N_h indicates the total number of farms in stratum h, and S_h stands for the standard deviation within stratum h.

Table 2. Provincial distribution of surveyed dairy farming enterprises.

Tablo 2. *Ankete katılan süt hayvancılığı işletmelerinin illere göre dağılımı*

Stratums (Animal no)	Gaziantep	Adıyaman	Kilis	TRC1
First stratum (01 - 30)	51	16	1	68
Second stratum (31 - 100)	34	18	4	56
Second stratum (101 – 101+)	15	6	0	21
Total	100	40	5	145

Grouping of Farms

The dairy farms included in the study were clustered based on calf mortality rates, and the resulting clusters were labelled as low, medium, and high mortality rates farms according to the average mortality rate within each cluster, ordered from lowest to highest. This clustering was performed using K-means analysis, and the formula used in this method is described as follows (MacQueen, 1967):

$$J = \sum_{j=1}^{k} \sum_{i=1}^{n} \|xi\ (j) - cj\|2$$

In this equation, J represents the objective function, k denotes the number of clusters, n indicates the total number of observations, xi is the ith observation, and cj signifies the centroid of the Jth cluster. The term ||xi (j) - cj|| denotes the distance function. The efficacy of the K-means clustering method was assessed using the Error Sum of Squares (SSE), defined as follows (Tan et al., 2006):

$$SSE = \sum_{i=1}^{K} \sum_{x \in C_i} dist^2 \langle m_i, x \rangle$$

In this context, "dist" represents the standard Euclidean distance, where x refers to a dairy farm situated within a cluster C_i, and m_i denotes the centroid of a cluster C_i. The K-means clustering analysis described operates based on the Euclidean distance criterion and continues iterating until no observations migrate between clusters. The formula for the Euclidean distance is given by:

$$d(x_i, x_j) = \sqrt{\sum_{k=1}^{p} (x_{ik} - x_{jk})^2}$$

Statistical analyses

A one-way ANOVA was conducted to compare clusters of farms based on mortality rates, using the Benjamini–Hochberg method to adjust for multiple comparisons (Benjamini & Hochberg, 1995). The statistical model applied is as follows:

$$Yi = \mu + Grpi + Cov + ei$$

where Yi represents the dependent variable, μ is the overall mean, Grpi is the group effect based on mortality rates, Cov is the covariate, and ei is the random error term.

For non-normally distributed variables, the Kruskal-Wallis H test was applied, and the Chi-Square test was used for categorical variables. Continuous variables that met normality assumptions were compared using the t-test, while the Mann-Whitney U test was used for nominal and ordinal data.

A multiple regression analysis was performed to examine the combined influence of various factors on calf mortality rates. The dependent variable was the calf mortality rate, and the independent variables included:

X1: Amount of colostrum given at the first feeding

X2: Amount of colostrum given at the second feeding

X3: Daily milk feeding frequency

X4: Daily total milk feeding amount

X5: Age at weaning

X6: Age at first water intake

X7: Age at first starter feeding

The regression model is represented as:

$$Y = \beta0 + \beta1X1 + \beta2X2 + \beta3X3 + \beta4X4 + \beta5X5 + \beta6X6 + \beta57X7 + \varepsilon$$

where Y is the calf mortality rate, β0 is the intercept, β1, β2, ..., β7 are the regression coefficients, and ε is the error term.

Correlation coefficients were computed to explore the relationships among variables. The Pearson correlation coefficient is calculated as follows:

$$r = \frac{\Sigma(Xi - X)(Yi - Y)}{\sqrt{\Sigma(Xi - \overline{X})^2 . \Sigma(Yi - \overline{Y})^2}}$$

where r is the correlation coefficient, Xi and Yi are individual data points, and X̅ and Y̅ are the means of the respective variables.

All statistical analyses were performed using IBM SPSS Statistics Version 20 (SPSS Inc., Chicago, IL, USA).

RESULTS

The research findings have been presented under three subheadings: (i) General characteristics and descriptive statistics of dairy farms, (ii) comparative analysis of clusters for calf mortality rate, and (iii) regression analysis and correlation results.

General Characteristics and Descriptive Statistics of Dairy Farms

Table 3 provides information on the general characteristics and descriptive statistics of dairy farms in the studied region. The average first colostrum intake (within 2 hours of birth) and second colostrum intake (within 12 hours of birth) for calves were 2.64 liters and 3.15 liters, respectively, with ranges of 1–10 liters for the first intake and 1–15 liters for the second intake. Milk feeding frequency averaged 2.08 times per day, with a range of 1 to 5 feedings, while the average duration of milk intake was 4.77 days, ranging from 2 to 10 days. The average weaning age was 85.21 days, with values ranging from 30 to 180 days. Water and starter feed intake began at average ages of 18.79 and 25.59 days, respectively, with ranges from 1 to 120 days for both. The average calf mortality rate was 7.81%, with a range from 1% to 30%.

Table 3. General characteristics and descriptive statistics of dairy farms.

Table 3. Süt işletmelerinin genel özellikleri ve tanımlayıcı istatistikleri.

Variables	Min	Max	Mean±Std.Dev.
1st Colostrum (Lt)	1	10	2.64±2.06
2nd Colostrum (Lt)	1	15	3.15±2.47
Milk feed frequancy (d)	1	5	2.08±0.48
Milk intake (d)	2	10	4.77±1.02
Weaning age (d)	30	180	85.21±29.39
1st Water intake (age/d)	1	120	18.79±23.19
1st Starter intake (age/d)	1	120	25.59±29.47
Mortality (%)	1	30	7.81±7.30

Table 4 provides insights into the general characteristics of dairy farms clustered by calf mortality rates—low, medium, and high. The mean calf mortality rates for the low, medium, and high mortality clusters were 3.25%, 5.05%, and 8.99%, respectively. In terms of colostrum intake, no statistically significant differences were observed between the clusters, although the medium mortality group had slightly higher means for both first and second colostrum intakes. Milk feeding frequency was consistent across all groups, averaging 2.00 times per day, while milk intake duration showed slight variation, with the medium mortality group having the highest mean duration. Regarding weaning age, the medium mortality group weaned calves earlier, with a mean age of 70.00 days, compared to the other clusters. For water and starter feed intake, the high mortality group exhibited much greater variability, particularly in the age at which starter feed intake began.

Table 4. General characteristics of dairy farms clustered by calf mortality rates.

Table 4. Buzağı ölüm oranlarına göre gruplanan süt çiftliklerinin genel özellikleri.

	Low mortality (N:18)			**Medium mortality (N:17)**			**High mortality (N:110)**		
Variables	**Min**	**Max**	**Mean±SD**	**Min**	**Max**	**Mean±SD**	**Min**	**Max**	**Mean±SD**
Mortality (%)	1	8	3.25±2.26^{a}	2	15	5.05±4.04^{ab}	1	30	8.99±7.83^{b}
1st Colostrum (Lt)	1	6	2.38±1.30	2	10	3.82±3.08	1	10	2.50±1.94
2nd Colostrum (Lt)	2	10	3.33±2.30	2	10	3.09±2.33	1	15	3.13±2.54
Milk feed frequancy (d)	2	2	2.00±0.00	2	2	2.00±0.00	1	5	2.11±0.55
Milk intake (d)	3	6	4.83±0.83	3.5	7	5.32±0.90	2	10	4.67±1.05
Weaning age (d)	60	180	87.50±35.96	60	90	70.00±11.62	30	180	87.15±29.73
1st Water intake (age/d)	1	21	9.67±7.39	1	15	5.91±3.70	1	120	22.278±25.48
1st Starter intake (age/d)	3	30	12.50±9.05^{ab}	1	30	8.00±8.19^{a}	1	120	30.46±32.04^{b}

a.b.c Values with different superscript letters within a row are statistically significant at the 0.05 level

Comparative Analysis of Clusters for Calf Mortality Rate

Table 5 provides a cluster-based analysis of factors affecting calf mortality rates, examining differences between the low, medium, and high mortality clusters. The analysis reveals that certain management practices show statistically significant variations across clusters, which may contribute to the observed differences in calf mortality rates.

The comparisons between clusters for first and second colostrum intake indicate no statistically significant differences (P>0.05). Milk feeding frequency also displayed no significant variation across clusters, as the feeding frequencies were consistently similar, with negligible mean differences.

For milk intake duration, slight differences were noted between clusters, though none reached statistical significance (P>0.05). However, weaning age demonstrated some variability, with the low mortality group averaging 17.50 days later than the medium mortality group, though this difference was not statistically significant (P>0.05). The age of first water intake also showed a greater difference between clusters, particularly between the low and high mortality groups, although these differences were not statistically significant.

The timing of the first starter intake displayed a significant difference (P<0.05) between the medium and high mortality groups, with the high mortality cluster showing a considerably later starter intake (22.46 days on average) compared to the medium mortality cluster (P<0.05).

Regression Analysis and Correlation Results

Table 6 presents the results of a regression analysis aimed at identifying factors influencing calf mortality rates. The analysis showed no statistically significant results, as indicated by the wide confidence interval (-8.53 to 15.78). For the variables related to colostrum intake, the coefficients for first and second colostrum volumes were -0.25 and -0.03, respectively, both of which were not statistically significant (P>0.05).

Milk feeding frequency (days) showed a positive coefficient of 0.71, but this was not statistically significant (P = 0.68). Similarly, milk intake per day had a negligible effect on mortality rates (β = -0.06, P = 0.94), with no significant association between milk intake and calf mortality.

Weaning age showed a positive association with calf mortality, though this was not statistically significant (P = 0.18). While the result was not significant, it suggests that a higher weaning age may be marginally associated with increased calf mortality. The variables for first water intake age (P = 0.28) and first starter intake age (P = 0.12) also demonstrated non-significant relationships with calf mortality rates. Overall, none of the variables in this model displayed statistically significant associations with calf mortality rates (P>0.05).

Table 5. Cluster-based analysis of factors affecting calf mortality rates.

Table 5. Buzağı ölüm oranlarını etkileyen faktörlerin kümeleme temelli analizi.

Variables	Cluster (I)	Cluster (J)	Mean Diff. (I-J)	Std. Err.	P-value *	95% CI	
						Low. Bound	Upp. Bound
1st Colostrum (Lt)	Low	Medium	-1.44	0.85	0.25	-3.51	0.62
		High	-0.13	0.63	1.00	-1.67	1.42
	Medium	Low	1.44	0.85	0.25	-0.62	3.51
		High	1.32	0.66	0.14	-0.28	2.92
	High	Low	0.13	0.63	1.00	-1.42	1.67
		Medium	-1.32	0.66	0.14	-2.92	0.28
2nd Colostrum (Lt)	Low	Medium	0.24	1.04	0.99	-2.29	2.77
		High	0.21	0.78	0.99	-1.68	2.10
	Medium	Low	-0.24	1.04	0.99	-2.77	2.29
		High	-0.03	0.81	1.00	-1.99	1.93
	High	Low	-0.21	0.78	0.99	-2.10	1.68
		Medium	0.03	0.81	1.00	-1.93	1.99
Milk feed frequancy (d)	Low	Medium	0.00	0.20	1.00	-0.49	0.49
		High	-0.11	0.15	0.84	-0.47	0.25
	Medium	Low	0.00	0.20	1.00	-0.49	0.49
		High	-0.11	0.16	0.85	-0.49	0.27
	High	Low	0.11	0.15	0.84	-0.25	0.47
		Medium	0.11	0.16	0.85	-0.27	0.49
Milk intake (d)	Low	Medium	-0.48	0.42	0.58	-1.51	0.54
		High	0.16	0.32	0.94	-0.61	0.93
	Medium	Low	0.48	0.42	0.58	-0.54	1.51
		High	0.64	0.33	0.15	-0.15	1.44
	High	Low	-0.16	0.32	0.94	-0.93	0.61
		Medium	-0.64	0.33	0.15	-1.44	0.15
Weaning age (d)	Low	Medium	17.50	12.18	0.39	-12.10	47.10
		High	0.35	9.10	1.00	-21.76	22.46
	Medium	Low	-17.50	12.18	0.39	-47.10	12.10
		High	-17.15	9.45	0.20	-40.11	5.80
	High	Low	-0.35	9.10	1.00	-22.46	21.76
		Medium	17.15	9.45	0.20	-5.80	40.11
1st Water intake (age/d)	Low	Medium	3.76	9.42	0.97	-19.14	26.65
		High	-12.61	7.04	0.21	-29.71	4.49
	Medium	Low	-3.76	9.42	0.97	-26.65	19.14
		High	-16.37	7.31	0.08	-34.12	1.39
	High	Low	12.61	7.04	0.21	-4.49	29.71
		Medium	16.37	7.31	0.08	-1.39	34.12
1st Starter intake (age/d)	Low	Medium	4.50	11.88	0.97	-24.36	33.36
		High	-17.96	8.87	0.13	-39.52	3.60
	Medium	Low	-4.50	11.88	0.97	-33.36	24.36
		High	-22.46*	9.21	0.05	-44.84	-0.08
	High	Low	17.96	8.87	0.13	-3.60	39.52
		Medium	22.46*	9.21	0.05	0.08	44.84

* The mean difference is significant at the 0.05 level.

Table 6. Regression analysis of factors influencing calf mortality rates.

Table 6. Buzağı ölüm oranlarını etkileyen faktörlerin regresyon analizi.

Variables	Coefficients		T-values	P-values *	95% CI	
	β	Std. Error			Lower	Upper
Intercept	3.63	6.12	0.59	0.55	-8.53	15.78
1st Colostrum (Lt)	-0.25	0.44	-0.57	0.57	-1.12	0.62
2nd Colostrum (Lt)	-0.03	0.37	-0.08	0.94	-0.77	0.71
Milk feed frequancy (d)	0.71	1.73	0.41	0.68	-2.72	4.15
Milk intake (d)	-0.06	0.78	-0.08	0.94	-1.61	1.49
Weaning age (d)	0.04	0.03	1.35	0.18	-0.02	0.09
1st Water intake (age/d)	-0.05	0.04	-1.09	0.28	-0.13	0.04
1st Starter intake (age/d)	0.05	0.03	1.59	0.12	-0.01	0.12

* The mean difference is significant at the 0.05 level.

The Pearson correlation matrix presented in Table 7 examines the relationships among various factors influencing calf mortality rates. Notably, the mortality rate showed a positive correlation with both weaning age (r = 0.18) and the age at first starter intake (r = 0.19). A moderate correlation was observed between first and second colostrum intake (r = 0.47), indicating a positive association between these variables. Additionally, a strong positive correlation was found between the age at first water intake and the age at first starter intake (r = 0.64), suggesting a concurrent progression in dietary development stages.

The correlations between milk feeding frequency and other factors, such as milk intake (r = -0.07) and weaning age (r = 0.09), were generally weak, indicating minimal direct associations. The correlation between milk intake and weaning age was negative (r = -0.27).

Overall, the matrix reveals a complex interplay of factors, where dietary transitions—represented by water and starter intake—are more strongly associated with calf development timelines than with direct influences on mortality rates.

Table 7. Pearson correlation matrix of factors influencing calf mortality rates.

Table 7. Buzağı ölüm oranlarını etkileyen faktörlerin Pearson korelasyon matrisi.

Pearson Correlations	Mortality (%)	1st Colostrum (Lt)	2nd Colostrum (Lt)	Milk feed frequancy (d)	Milk intake (d)	Weaning age (d)	1st Water intake (age/d)	1st Starter intake (age/d)
Mortality (%)	1.00	-0.09	-0.01	0.08	-0.06	0.18	0.05	0.19
1st Colostrum (Lt)	-0.09	1.00	0.47	-0.06	0.05	0.01	-0.17	-0.17
2nd Colostrum (Lt)	-0.01	0.47	1.00	0.30	-0.01	0.06	-0.05	0.00
Milk feed frequancy (d)	0.08	-0.06	0.30	1.00	-0.07	0.09	-0.06	0.04
Milk intake (d)	-0.06	0.05	-0.01	-0.07	1.00	-0.27	-0.24	-0.19
Weaning age (d)	0.18	0.01	0.06	0.09	-0.27	1.00	0.32	0.34
1st Water intake (age/d)	0.05	-0.17	-0.05	-0.06	-0.24	0.32	1.00	0.64
1st Starter intake (age/d)	0.19	-0.17	0.00	0.04	-0.19	0.34	0.64	1.00

DISCUSSION and CONCLUSION

The findings of this study highlight the complex relationship between management practices and calf mortality rates in dairy farms across the Gaziantep region of Türkiye. Given the significance of early-life calf management in determining long-term productivity and sustainability in dairy farming, it is critical to explore how specific practices can mitigate mortality risk.

The statistics revealed notable variability in several key management areas, which may significantly influence calf health and mortality outcomes. This variability suggests differing approaches to colostrum feeding that could affect passive immunity transfer. However, despite the established importance of colostrum in promoting calf health, our analysis revealed no statistically significant differences in mortality outcomes based on colostrum intake among the various clusters in the studied region. It is important to note that, in all three enterprise groups (low, medium, and high mortality), the first and second colostrum intakes were within the recommended ranges for calf health, suggesting that colostrum intake alone is unlikely to explain the variation in mortality rates. This finding aligns with the previous studies, which suggested that while timely and adequate colostrum feeding is essential, other factors may also contribute to the observed mortality rates (Abuelo et al., 2021; Abuelo et al., 2019; Barry et al., 2019). Although calves receiving higher volumes of colostrum demonstrated improved passive immunity, the absence of a significant impact on mortality in these studies suggests that additional interventions may be necessary to enhance calf survival. These interventions could include vaccination against septicemia and pneumonia, two of the primary causes of calf mortality. While vaccination is an important preventative measure, it is clear that other factors, beyond colostrum intake and vaccination, contribute to mortality outcomes. Some of these factors may include environmental conditions such as temperature fluctuations, humidity, and the cleanliness of the barns. Previous research has shown that poor hygiene and inadequate environmental conditions can exacerbate disease transmission and increase the likelihood of calf infections (Khan et al., 2020). Furthermore, stress from handling, transportation, or overcrowding could compromise the immune system, making calves more susceptible to disease, even with adequate vaccination.

The data indicated a uniform average milk feeding frequency across clusters, suggesting that other management aspects, such as the quality of milk and the feeding environment, may play a more critical role in calf health. The lack of significant variation in milk intake duration further underscores the need for dairy producers to focus on the broader context of feeding management, including the nutritional quality of milk and adherence to feeding protocols. Previous studies have pointed out that while feeding frequency might not directly correlate with mortality, it is essential for optimizing growth and development during this critical period (Johnson et al., 2021; Mohammed et al., 2020; Zhao et al., 2021). This suggests a potential area for future research to explore the qualitative aspects of feeding alongside quantitative measures.

Weaning age emerged as a noteworthy factor, particularly in the comparative cluster analysis. Although the differences were not statistically significant, earlier weaning in the medium mortality group suggests the need for a more cautious approach to weaning practices. The data revealed differences in weaning strategies across farms, highlighting the potential for earlier weaning practices to contribute to calf stress and health challenges. Previous literature has highlighted the stress associated with early weaning, which can negatively affect calf health and subsequent productivity (Bittar et al., 2020; Mikuš & Mikuš, 2020; Nicolao et al., 2022; Wenker et al., 2022). The data also suggest that calves weaned earlier may have higher mortality rates, although these correlations were relatively weak. Future investigations could benefit from a more in-depth examination of the physiological and behavioral implications of weaning strategies, potentially guiding farmers toward practices that support healthier transitions.

Our findings also suggest a possible link between the timing of water and starter feed intake and calf mortality rates. The positive correlation between the age of first starter intake and mortality points to the potential benefits of earlier introductions of solid feed, which could foster better rumen development and overall health, consistent with previous studies (Arshad et al., 2021; Lorenz, 2021; Palczynski et al., 2020; Shiasi Sardoabi et al., 2021). Additionally, the findings emphasize differences in early feeding practices across farms, which could influence hydration, rumen development, and overall calf growth. The wide variability in the timing of starter intake across farms suggests an opportunity for standardizing feeding protocols to enhance consistency in calf growth and health outcomes. This could be crucial, as delayed starter intake might be associated with higher mortality rates, potentially impacting rumen development and overall calf growth.

This study stresses the necessity for dairy farmers to adopt a comprehensive approach to calf management that integrates feeding practices, weaning age strategies, and environmental considerations. Implementing evidence-based interventions, such as standardizing colostrum management and optimizing weaning practices, may significantly reduce calf mortality rates. Additionally, educating farmers about the critical role of timely starter feed introduction and access to clean water could further bolster calf health. While this study provides valuable insights, it is essential to acknowledge its limitations, including the relatively small sample size and the potential for unmeasured confounding factors. Future research should aim to include a larger and more diverse set of dairy farms to enhance the generalizability of the findings. Longitudinal studies could also provide a deeper understanding of the causal relationships between management practices and calf mortality outcomes.

In conclusion, the interplay of management practices significantly influences calf mortality rates in dairy farming. By focusing on standardized, evidence-based practices, dairy producers can enhance calf survival, improve overall herd health, and contribute to the sustainability of dairy farming operations. The findings from this study serve as a foundation for further research and practical applications aimed at minimizing calf losses and optimizing dairy farm productivity.

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