Biological Forum – An International Journal 13(4): 392-397(2021)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Potential Hazardous Factors Affecting Survival of Mecheri Lambs

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(Received 19 August 2021, Accepted 25 October, 2021)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Survival analysis is an essential step for understanding lamb survival function and the hazardous factors affecting mortality rate. The survival data of 3715 Mecheri lambs born during the period from 1979 - 2018 at Mecheri Sheep Breeding Research Station, Pottaneri, Tamil Nadu were utilized for the analysis. Kaplan - Meier approach was used to estimate the survival function of lambs. The survival analysis with Cox proportional hazard model was carried out to assess the impactful factors of lamb mortality. Mortality in different growth intervals viz., birth to 3 months, 3 months to 6 months, 6 months to 9 months and 9 months to 12 months were recorded as 6.05 %, 4.74 %, 2.1% and 1.37 %, respectively. In all the four growth groups, male lambs were having higher hazard rate than females and the survival rate is higher for lambs born in main season than in off season. The survival rate of lambs with high birth weight was comparatively superior to the lambs having lesser birth weight. In conclusion, it is suggested to practice the genetic selection for improving birth weight; planned mating for lambing in main season; and to give utmost care to pregnant ewes and male lambs for the improvement in survivability of Mecheri lambs.

Keywords: Mecheri sheep, Mortality, Survival rate, Kaplan Meier curve, Cox regression.

INTRODUCTION

Sheep population in India is 74.26 million, which contributes 13.87 per cent of the total livestock population of India (20th Livestock Census, 2019). With 4.5 million sheep population in Tamil Nadu, the state stands fifth position among all the states in India. Mecheri is one among the seven hairy breeds of sheep in Tamil Nadu, and mainly reared for meat and it plays a crucial role in farmers economy by fulfilling their instant requirements. Lamb mortality is a critical component in sheep farming, which creates direct economic losses to farmers. Understanding of the factors affecting the lamb mortality is essential for making interventions to reduce the economic losses in sheep industry. Mecheri lambs were not assessed for hazard factors. The survival analysis is the method of choice for studying the lamb mortality and its associated factors. Hence, this study of survival analysis was designed to carry out in Mecheri lambs.

MATERIALS AND METHODS

Survival data of 3715 Mecheri lambs born at Mecheri Sheep Breeding Research Station (MSRS), Pottaneri, Tamil Nadu during the period from 1979 to 2018 were collected along with their birth weight, for survival analysis. The sex of the lambs (male and female), parity of the dam (1, 2, 3, 4 and above), period of birth (8 categories), type of birth (single and twin births), and season of birth (main and off season) were used to classify Mecheri lambs. Mecheri sheep have two breeding seasons: Main (September and October) and Off (March to April). The lambing seasons were classified based on the breeding seasons of Mecheri ewes. Survival analysis was carried out for Mecheri lambs at different age intervals viz., birth to 3 months, birth to 6 months, birth to 9 months and birth to 12 months. Standard feeding and management procedures were followed consistently throughout the period, and genetic selection has been practised to improve the animals in the farm.

STATISTICAL ANALYSIS METHOD

Descriptive statistics was carried out for deriving the mortality percentage in Mecheri lambs during their different growth periods. Kaplan-Meier approach provides accurate survival estimates by re-estimating the survival probability each time an event/death occurs. (Kaplan and Meier, 1958). Kaplan-Meier survival analysis was performed for detailing the lamb survival function with survival curve and mean survival time, for each age interval category. In each age interval category, the sold and alive animals together named as censored. The survival time (S_t) of each lamb was estimated by the product limit method, given by of Kaplan and Meier (1958).

$$S_t = \prod_{t_i \leq t} 1 - \frac{d_i}{n_i}$$

Where, t_i is the duration of study at any point 'i', d_i is the mortality of lambs up to the point 'i' and n_i is the number of lambs at risk just prior to t_i.

Cox proportional hazard model (Cox, 1972) was used in the analysis to assess the effect different factors on survival of Mecheri lambs. Goodness of fit for the Cox proportional hazard model was confirmed with Global Chi-Square and Likelihood Ratio tests (Table 2) and proceeded further for survival analysis in Sigmaplot 14.5 (Systat Software Sigma Plot 14.5. The following Cox proportional hazard model (Collet, 2003) was used in the survival analysis:

$$h_i(t) = h_0(t) \exp(b_1 X_{i1} + b_2 X_{i2} + \ldots\ldots + b_k X_{ik})$$

Where, h_i (t) is the hazard function at i^{th} point of time in the survival period t, which was determined by baseline hazard function ($h_0(t)$) and a set of covariates defined by X_i. Sex of lamb, period of birth, season of birth, type of birth, parity order of dam and birth weight were used as covariates in this analysis. Baseline hazard function represents the probability of dying when all explanatory variables are equal to zero. By taking natural logarithm, the hazard function was transformed as a linear fixed-effects proportional hazard model and simplified the estimation of hazard ratio for covariates.

$$\ln[h_i(t)] = \ln[h_0(t)]\ (b_1 X_{i1} + b_2 X_{i2} + \ldots\ldots + b_k X_{ik})$$

Hazard rates for the covariate categories and the continuous covariate were derived from regression coefficients. The hazard ratio [h_i (t)/h_0 (t)] for a covariate was computed as the proportional change in the hazard rate due to a unit change in the value of the covariate. For a group from a categorical covariate, the hazard ratio was calculated as the ratio of the hazard rate of the group to the hazard rate of the reference group. In each categorical covariate, the reference group was identified based on the the baseline hazard function. Kaplan-Meier and Cox proportional hazard analysis were carried out in Sigmaplot version 14.5 (SigmaPlot 14.5, Systat Software Inc.). Goodness of fit for Cox proportional hazard model was confirmed with Likelihood Ratio tests. Chi-square test was applied for testing the significance of the continuous covariate and categorical covariates on hazard rate.

RESULTS AND DISCUSSIONS

A. Mortality and survival function

In Mecheri lambs, mortality was recorded as 6.05, 4.74, 2.1 and 1.37 per cent during the growth intervals from birth to weaning, weaning to 6 months, 6 months to 9 months and 9 months to 12 months respectively. These results revealed a decreasing trend in mortality with increasing age. Among the age intervals of Mecheri lambs, higher death percentages were found in 0-3 months (6.05 %) and 3-6 months (4.74 %). This clearly shows that the critical age groups for survival of Mecheri lambs were 0-3 months and 3-6 months. Similar findings were reported earlier in Mecheri (Thiruvenkadan *et al.*, 2003; Jeichitra *et al.*, 2013) and Iranian Kermani sheep (Barazandeh *et al.*, 2012). The largest mortality has been recorded in the first quarter (0-3 months) of the growth period of lambs in most Indian sheep breeds (Thiruvenkadan *et al.*, 2003; Mandal *et al.*, 2007; Bangar *et al.*, 2016). However, Soundararajan (2014) found that postweaning mortality was higher than preweaning mortality in Madras Red sheep.

The mean survival time of lambs during the growth intervals of birth to 3 months, birth to 6 months, birth to 9 months, and birth to 12 months was 87.49 days, 169.50 days, 248.56 days, and 326.26 days, respectively (Table 1). It was found that the preweaning period had the largest of proportionate mean survival time. In agreement with the results of Getachew *et al.* (2015), survival function graphs (Figs. 1-4) showed a gradual decline in curve except during the first few days after the birth of lambs. A total of 24 lamb deaths were happened during the first three days of life of lambs with the average of eight deaths in a day. The preweaning phase survival curve suggested that the first few days following delivery of lambs require close monitoring and care to prevent lamb loss. The higher lamb mortality seen in this study immediately after birth is consistent with the past investigation by Southey and Leymaster (2008). Due to a shift in the lamb environment, survival of lambs is critical during the early stages of life after birth (Vatankhah and Talebi, 2009). Enhancing lambing environment for ewes, increasing lamb birth weight, and improving management at birth may contribute to reduced lamb mortality (Tibbo, 2006; Hatcher *et al.*, 2010). The reduced steepness of the survival curve in the last growth period of this study indicated the low death rate in lambs during that period. Bangar *et al.* (2016) reported the similar survival function in Deccani sheep for the preweaning growth period.

Table 1: Mean survival time with 95 % Confidence Interval (CI).

Category	Survival Time (days)	95% CI-Lower limit	95% CI- Upper limit
Birth to 3 months	87.49 ± 0.20	87.10	87.87
Birth to 6 months	169.50 ± 0.56	168.39	170.60
Birth to 9 months	248.56 ± 1.02	246.57	250.55
Birth to 12 months	326.26 ± 1.51	323.29	329.22

*****-Significantly different from the reference group

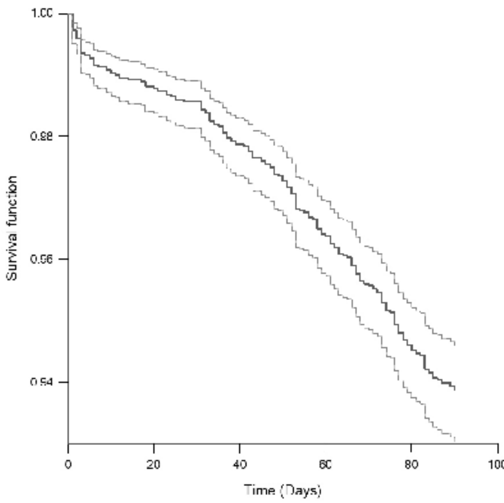

Fig. 1. Kaplan Meier survival curve for Mecheri lambs (birth to 3 months)

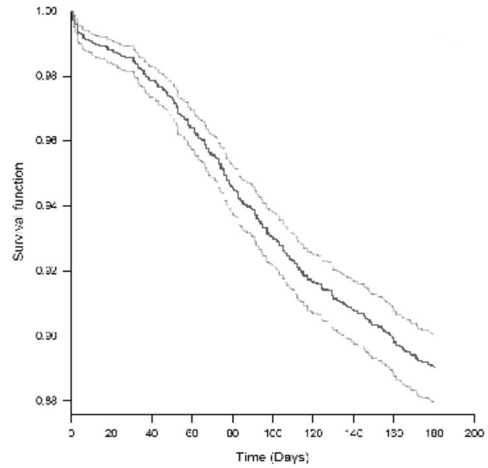

Fig. 2. Kaplan Meier survival curve for Mecheri lambs (birth to 6 months).

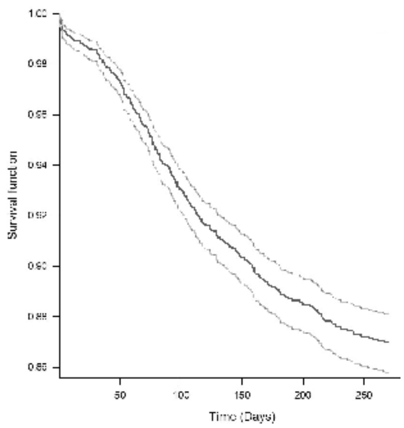

Fig. 3. Kaplan Meier survival curve for Mecheri lambs (birth to 9 months).

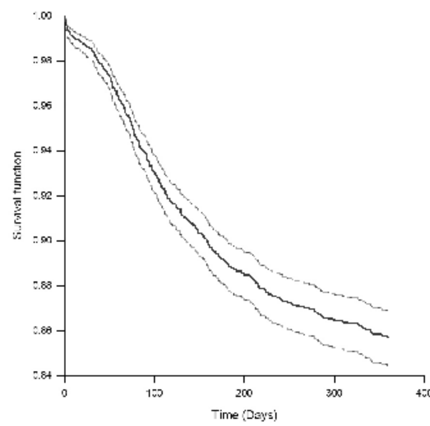

Fig. 4. Kaplan Meier survival curve for Mecheri lambs (birth to 12 months).

Hazard rate and hazard ratio. The hazard rates and hazard ratios of different covariates in different growth intervals were presented in Tables 2-5. In this study, the negative hazard rates observed for categorical covariates showed that lambs in the corresponding subgroup died at a lower rate than lambs in the reference group. In other words, a negative hazard rate suggests that lambs are more likely to survive. Significant effect ($P<0.05$) of period of birth, sex of lambs and birth weight on survival of lambs were observed in all the growth periods in the study. Additionally, a significant influence of season ($P<0.05$) was identified during the birth to nine-month and birth to twelve-month period, as well as parity during the preweaning phase.

The significant negative hazard rate of birth weight in the study indicated that when birth weight increases, the survival rate increases as well. The birth weight hazard ratios demonstrated that for every kg increase in birth weight, the risk of death fell by 0.24, 0.30, 0.35, and 0.36 times during the preweaning, birth to six-month, birth to nine-month and birth to twelve-month periods, respectively. Indirectly, this indicates that lamb survival increased with birth weight. Bangar *et al.* (2016) found a comparable effect of birth weight on preweaning lamb survival, with a hazard ratio of 0.18. Chauhan *et al.* (2019) also discovered a similar relationship between birth weight and hazard rate.

The periods of birth, 1995-1999, 2005-2008, and 2009-2013 in the preweaning duration, had significantly different hazard rates compared to the 1979-1984 reference period. The varying death rates in different period could be attributable to pasture availability and varying quantity of rainfall over the periods (Thiruvenkadan *et al.*, 2018). The computed hazard rates and hazard ratios of the sub groups of different periods of birth for the growth intervals birth to six months, birth to nine months, and birth to twelve months indicated that lamb survival had increased over time The increased lamb survival rate over periods may be the result of genetic selection and improved farm management practices.

Table 2: Hazard rate and hazard ratio of factors affecting survival of Mecheri lambs (Birth to 3 months).

Factor	Hazard rate with SE	Wald Chi-Square	P Value	Hazard Ratio (95%CI)
Period	Reference group:1979-1984			
1985-1989	0.373 ± 0.216	2.977	0.084	1.452 (0.951, 2.219)
1990-1994	-0.469 ± 0.278	2.851	0.091	0.625 (0.363, 1.078)
1995-1999	-0.725 ± 0.287*	6.377	0.012	0.484 (0.276, 0.850)
2000-2004	-0.092 ± 0.214	0.185	0.667	0.912 (0.599, 1.388)
2005-2008	-2.375 ±0.412*	33.174	<0.001	0.093 (0.041, 0.209)
2009-2013	-3.055 ± 0.728*	17.587	<0.001	0.047 (0.011, 0.197)
2014-2018	-0.294 ±0.273	1.159	0.282	0.745 (0.436, 1.273)
Season	Reference group: Main season			
Off season	-0.293 ± 0.172	2.909	0.088	0.746 (0.533, 1.045)
Birth type	Reference group: Single			
Twin	0.225 ± 0.525	0.184	0.668	1.253 (0.448, 3.502)
Parity	Reference group: Parity_1			
Parity_2	-0.246 ± 0.166	2.191	0.139	0.782 (0.564, 1.083)
Parity_3	-0.553 ± 0.250*	4.893	0.027	0.575 (0.352, 0.939)
Parity_4	-0.173 ± 0.254	0.463	0.496	0.841 (0.512, 1.384)
Sex	Reference group: Female			
Male	0.270 ± 0.134*	4.047	0.044	1.310 (1.007, 1.705)
Birth weight	-1.427 ± 0.159*	81.024	<0.001	0.240 (0.176, 0.327)

Table 3: Hazard rate and hazard ratio of factors affecting survival of Mecheri lambs (Birth to 6 months).

Factor	Hazard rate with SE	Wald Chi-Square	P Value	Hazard Ratio (95 % CI)
Period	Reference group: 2000-2004			
1979-1984	0.436 ± 0.170*	6.579	0.010	1.547 (1.108, 2.159)
1985-1989	0.764 ± 0.160*	22.653	<0.001	2.146 (1.567, 2.940)
1990-1994	0.264 ± 0.192	1.885	0.170	1.302 (0.893, 1.898)
1995-1999	0.060 ± 0.192	0.099	0.752	1.063 (0.729, 1.549)
2005-2008	-1.792 ± 0.284*	39.925	<0.001	0.167 (0.095, 0.290)
2009-2013	-1.592 ± 0.322*	24.379	<0.001	0.204 (0.108, 0.383)
2014-2018	-0.192 ± 0.239	0.646	0.422	0.825 (0.516, 1.319)
Season	Reference group: Off season			
Main season	-0.205 ± 0.124	2.716	0.099	0.815 (0.638, 1.040)
Birth type	Reference group: Single			
Twin	0.446 ± 0.425	1.102	0.294	1.562 (0.679, 3.592)
Parity	Reference group: Parity_1			
Parity_2	0.020 ± 0.125	0.0271	0.869	1.021 (0.798, 1.305)
Parity_3	-0.276 ± 0.178	2.409	0.121	0.759 (0.536, 1.075)
Parity_4	0.004 ± 0.178	0.000590	0.981	1.004 (0.709, 1.423)
Sex	Reference group: Female			
Male	0.274 ± 0.103*	7.032	0.008	1.316 (1.074, 1.611)
Birth weight	-1.204 ± 0.122*	96.897	<0.001	0.300 (0.236, 0.381)

*****-Significantly different from the reference group.

Table 4: Hazard rate and hazard ratio of factors affecting survival of Mecheri lambs (Birth to 9 months).

Factor	Hazard rate with SE	Wald Chi-Square	P Value	Hazard Ratio (95% CI)
Period	Reference group: 2000-2004			
1979-1984	0.425 ± 0.163*	6.757	0.009	1.529 (1.110, 2.106)
1985-1989	0.779 ±0.157*	24.696	<0.001	2.180 (1.603, 2.965)
1990-1994	0.415 ±0.178*	5.450	0.020	1.515 (1.069, 2.146)
1995-1999	0.350 ±0.173*	4.107	0.043	1.419 (1.012, 1.990)
2005-2008	-1.675 ±0.262*	40.968	<0.001	0.187 (0.112, 0.313)
2009-2013	-1.279 ±0.268*	22.757	<0.001	0.278 (0.164, 0.471)
2014-2018	-0.273 ±0.236	1.335	0.248	0.761 (0.479, 1.210)
Season	Reference group: Off season			
Main	-0.269 ±0.117*	5.244	0.022	0.764 (0.607, 0.962)
Birth type	Reference group: Single			
Twin	0.435 ±0.423	1.058	0.304	1.545 (0.674, 3.539)
Parity	Reference group: Parity_1			
Parity_2	-0.014 ±0.120	0.014	0.905	0.986 (0.779, 1.247)
Parity_3	-0.264 ±0.163	2.604	0.107	0.768 (0.558, 1.058)
Parity_4	0.136 ±0.154	0.776	0.378	1.146 (0.847, 1.551)
Sex	Reference group: Female			
Male	0.229 ±0.096*	5.621	0.018	1.258 (1.041, 1.520)
Birth weight	-1.040 ± 0.115*	81.804	<0.001	0.353 (0.282, 0.443)

*****-Significantly different from the reference group

Table 5: Hazard rate and hazard ratio of factors affecting survival of Mecheri lambs (Birth to 12 months).

Factor	Hazard rate with SE	Wald Chi-Square	P Value	Hazard Ratio (95 % CI)
Period	**Reference group: 2000-2004**			
1979-1984	0.449 ±0.159*	7.954	0.005	1.567 (1.147, 2.142)
1985-1989	0.776 ±0.155*	25.035	<0.001	2.172 (1.603, 2.943)
1990-1994	0.548 ±0.169*	10.513	0.001	1.730 (1.242, 2.410)
1995-1999	0.408 ±0.168*	5.933	0.015	1.504 (1.083, 2.090)
2005-2008	-1.601 ±0.250*	41.023	<0.001	0.202 (0.124, 0.329)
2009-2013	-1.179 ±0.257*	21.098	<0.001	0.308 (0.186, 0.509)
2014-2018	-0.268 ±0.232	1.332	0.248	0.765 (0.486, 1.206)
Season	Reference group: Off season			
Season - Main	-0.298 ±0.114*	6.826	0.009	0.743 (0.594, 0.928)
Birth type	Reference group: Single			
Twin	0.393 ±0.422	0.870	0.351	1.482 (0.648, 3.388)
Parity	Reference group: Parity_1			
Parity - Parity_2	-0.0317 ±0.116	0.0745	0.785	0.969 (0.772, 1.216)
Parity_3	-0.303 ±0.158*	3.664	0.056	0.739 (0.541, 1.007)
Parity_4	0.0539 ±0.151	0.128	0.721	1.055 (0.785, 1.419)
Sex	Reference group: Female			
Sex - Male	0.219 ±0.093*	5.435	0.020	1.244 (1.035, 1.495)
Birth weight	-1.013 ±0.111*	82.816	<0.001	0.363 (0.292, 0.452)

*****-Significantly different from the reference group

Male lambs had death rates that were 1.310, 1.316, 1.258, and 1.244 times that of female lambs during the preweaning, birth to six-month, birth to nine-month, and birth to twelve-month periods, respectively. Several scientists have observed that male lambs die at a higher rate than female lambs (Mandal *et al.*, 2007; Vostry and Milerski, 2013; Hatcher *et al.*, 2010). Metabolic rates in males are likely to be faster than females, which means that the effects of additional stress may be more devastating, resulting in a higher mortality rate (Getachew *et al.*, 2015). Comparatively, male lambs had a higher risk of death from respiratory, digestive, and other reasons than female lambs, as previously reported in prior studies (Mukasa-Mugerwa *et al.*, 2000, Mandal *et al.*, 2007). Certain behaviours have been linked to sex, such as ewes prioritizing ewe lambs when providing colostrum, making males more susceptible to pathogens (Tibbo, 2006).

Hazard rates computed for the growth periods of birth to nine months and birth to twelve months revealed that the main season had much lower hazard rates than the off season. It implied that lambs born in the main season had a better chance of survival than lambs born in the off season. The post weaning periods for the majority of main season born lambs occur during the two rainy seasons of the farm location. The sufficient pasture available throughout the post weaning growing phases may explain why lambs born during the main season have a higher survival rate. The relationship between lambing season and lamb survival has been explored in a variety of breeds (Mukasa-Mugerwa *et al.*, 2000; Vatankhah and Talebi, 2009; Bangar *et al.*, 2016), and is mostly influenced by pasture availability.

A statistically significant effect of parity on lamb mortality was observed during the preweaning growth phase, with a hazard ratio of 0.575 for third parity. This is in contrast to the findings of Getachew *et al.*, (2015) who have reported a non-significant effect parity. Although lambs born from twin births died at a higher rate than lambs born from single births, the difference was not statistically significant in this study.

CONCLUSION

Survival analysis revealed a higher incidence of death during the first few days after birth and a significant percentage of mortality over the growth phases of birth to three months and three to six months. Cox regression analysis revealed that the factors viz., birth weight, sex of lamb, season of birth and period of birth as potential factors which affected the survival of Mecheri lambs. Male lambs faced more risks than female lambs, and lambs born during the main season performed better than lambs born during the off season. Birth weight was critical for lamb survival in all age groups of Mecheri sheep. Among the periods of birth, the later periods have lower hazard rates. According to the findings of this study, the following practices are recommended for further improving the survival of Mecheri lambs: genetic selection for birth weight; intensive care of male lambs during the preweaning period; and mating planning to minimize number of lamb births during the off season. In the future, the impacts of inbreeding on lamb survival may be investigated and incorporated into strategies for improving the survivability of Mecheri lambs.

Acknowledgement. Authors are grateful to the University, TANUVAS, for providing necessary support to accomplish this work which is a part of Ph.D. research work.
Conflict of Interest. None.

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How to cite this article: Balasundaram, B.; Thiruvenkadan, A.K.; Murali, N.; Muralidharan, J. and Cauveri, D. (2021). Potential Hazardous Factors Affecting Survival of Mecheri Lambs. *Biological Forum – An International Journal, 13*(4): 392-397.