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A benchmark study of dairy calf mortality rates on the Islands of Malta and Gozo

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ABSTRACT

The aim of this study was to determine the overall mortality rates of live born calves up to 180 days of age in dairy herds on the islands of Malta and Gozo. Five risk factors, namely: the island of birth, sex of calf, average herd size, the year and season of birth, were also studied. The data set used in the study consisted of a total of 44,078 calves, born between 1 January 2004 and 31 December 2011, from all the dairy herds of both islands. From this dataset, 28,848 calves were born on Malta and 15,230 on Gozo. In total 2,821 calves were registered as having died before reaching 180 days of age. The overall calf mortality rate in live born calves up to 180 days of age was found to be 7.08 %. On Malta the overall mortality rate was 6.05 % and on Gozo 8.80 % ($P<0.001$). The overall mortality rate was 8.48 % for male calves and 5.99 % for females ($P<0.001$). Holdings with a lower average herd size had a significantly lower calf mortality rate ($P = 0.01$), whereas no significant difference was found when the season of birth was taken into consideration. A significant difference ($P<0.001$) was present when calf mortality was stratified by the year of birth, with the last 3 years of the study having a lower mortality rate than the first 5 years. This study is of relevance since calf mortality rates and the risk factors described are being investigated for the first time on Malta and Gozo.

Key words: dairy calf, Gozo, Malta, mortality rate, risk factor

Introduction

The study of calf mortality is of particular relevance from both an economic and also from an animal welfare point of view (FRASER and BROOM, 1997). As a result, establishing calf mortality rates is one of the steps towards evaluating the efficiency and welfare of the dairy sector on the Maltese Islands. The dairy industry is the predominant industry within the bovine husbandry sector on the islands of Malta and Gozo, and establishing a

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benchmark mortality rate is therefore of importance to this industry. It is also important to compare local data on mortality rates with calf mortality rates in other countries, since this gives a good indication of the state of animal health and welfare on dairy holdings on the Maltese Islands.

Published estimates of calf mortalities vary according to the time periods in which calves are followed throughout the study, and according to whether or not data for abortions and stillbirths are also included. In fact, according to RADOSTITS (2001), calf mortality can be divided into four groups depending on the age at time of death: abortion or prenatal deaths (stillborn calves from 40 to 270 days of gestation), perinatal mortality (stillborn after 270 days of gestation or until 24 h after birth), neonatal mortality (death between 1 and 28 days of age), and older calf mortality (death between 1 and 6 months of age). This variation in how data is collected makes comparisons across countries more difficult.

Several authors have reported calf mortality rates in different countries. These include calf mortality rates of 4.6 % in live born dairy calves up to 1 year of age in Norway (GULLIKSEN et al., 2009), 4.0 % in live born dairy calves up to 210 days of age in Sweden (SVENSSON et al., 2006) and an average of 2.0 % to 6.0 % on British cattle farms for calves followed up to six months of age (ORTIZ-PELAEZ et al., 2008). A study carried out by the Department of Environment, Food and Rural Affairs of the United Kingdom (UK), estimates that up to 6.0 % of calves born in the UK die before reaching 6 months of age (DEFRA, 2003). AZIZZADEH et al. (2012) report a mortality rate of 6.5 % in live born dairy calves up to 90 days of age in Iranian Holstein dairy herds.

The objectives of this study were to determine, for the first time, the overall live born calf mortality rates up to 180 days of age in dairy herds on the Maltese Islands, and to study five risk factors, which included: the island on which the calves were born, the sex of the calves, the average herd size of the holding on which the calves were born and reared, the season of birth of the calves, and their year of birth. Some of these risk factors have been investigated in other countries by a number of authors, including JENNY et al. (1981), WALTNER-TOEWS et al. (1986a, b), WELLS et al. (1996), SVENSSON et al. (2006) and GULLIKSEN et al. (2009).

Materials and methods

Collection of data. This study was performed using data pertaining to all the dairy herds present on the islands of Malta and Gozo. On both islands all dairy herds are registered in the Maltese National Livestock Database (NLD). The NLD was introduced in 2002 and was recognised as being fully operational by the European Union (EU) in 2004 (European Commission, 2004).

All bovine herds on the Maltese Islands have to be registered with the Veterinary and Phytosanitary Regulation Department (VPRD), which currently forms part of the Ministry for Sustainable Development, the Environment and Climate Change (Government of Malta, 2005a, b). Furthermore, it is mandatory to tag all calves within 20 days of birth (Government of Malta, 2005a). As a result all tagged bovines on the Islands of Malta and Gozo can be traced through the centralised NLD.

In the NLD, exits of bovines from dairy holdings are coded as individual events. These events include bovines which are slaughtered, sold, or those dying on the holding. The date of death has to be reported by the owner within 7 days of the event occurring (Government of Malta, 2005a).

Study design. A retrospective longitudinal study was conducted on all the dairy herds present on the islands of Malta and Gozo and registered in the NLD. The study period was from 1 January 2004 to 30 June 2012. A total of 162 dairy holdings were active during all or part of the study period. One hundred and thirteen of these dairy holdings were located on Malta and 49 on Gozo. All calves born alive from 1 January 2004 to 31 December 2011 were followed for 180 days from their date of birth. Calves included in the study were all ear tagged and could be traced up to the date of notification of death or, if still alive, up to 180 days from the date of birth. For the purposes of this study, the death of a calf was registered as an event when it was born alive and notification was given that it had died by any cause before 180 days of age on the same holding of birth. Calves that were slaughtered or sold before 180 days of age, or those that were still alive at the end of the follow up period of 180 days were censored on the date of slaughtering, sale or at 180 days of age respectively.

Mortality rate is defined by DOHOO et al. (2009) as the number of animals that die from all causes in a defined time period. It is calculated as the number of animals that die in a population per unit of animal-time during a given time period. In this study the calf mortality rate was determined by calculating the number of deaths per total number of calf-time at risk (days).

A total of 44,078 calves were included in the study, of which 28,848 were born on Malta and 15,230 on Gozo. In total 2,821 calves were registered as having died on the same holding where they were born before reaching 180 days of age. For these calves the date of death was considered as the failure time. For the surviving calves, day 180 was considered as the failure time.

Only dairy herds were included in the study since 85.43 % and 98.91 % of bovines on Malta and Gozo, respectively, were present on dairy holdings during the study period. The majority of non-dairy holdings are small holdings, mostly managed on a part-time basis, and they buy in young calves from the dairy holdings to fatten and slaughter.

Statistical methods. The data collected was transferred from the NDL to Microsoft Excel files, where data verification and validation was carried out. The data were then transferred to two statistical packages (SPSS version 21 and STATA 12), where survival analysis was performed.

The five risk factors studied were: the island on which the calves were born, the sex of the calves, the average herd size of the holding on which the calves were born and reared, the season of birth, and the year of birth of the calves. The season of birth variable was coded as a categorical variable of four levels according to the date of birth of each calf. Calves born from March to May were registered as being born in spring, in June to August as summer, in September to November as autumn and in December to February as winter. The holdings where the calves were born and reared were divided into six groups according to the average herd size of the holding during the study period: ≤25 bovines, 26-50, 51-100, 101-200, 201-300 and >300 bovines. To calculate the average herd size, the database was used to locate all the animals that were present on each holding at any time during the study period. The number of days during which each animal was present during the period (animal-days) was then calculated. The total number of animal-days divided by the number of days in the period gives the average herd size on any particular holding.

Survival analysis, including life tables, Kaplan-Meier curves and Cox regression analysis, was used to account for any calves censored during the study due to sale or slaughter before 180 days and due to right censoring at the end of the study period.

A Cox proportional hazard model was used to evaluate the association between the five risk factors and the survival of calves up to 180 days of age. The assumption for proportional hazards was met. A backward stepwise approach was used to select the risk factors that best explained calf survival. Those risk factors that were not statistically significant at $P<0.05$ were removed from the model one at a time until only the statistically significant variables were left.

The hazard function plot gave a humped profile, and the two appropriate distributions for the parametric model are the Log-normal and Log-logistic distributions. Both the Akaike information criterion (AIC) and the Bayesian information criterion (BIC) indicate that the Log-normal Accelerated failure time (AFT) parametric model provides the best fit. This model was further used to evaluate the outcome of the variables in the study using STATA 12, and no statistically significant differences were encountered from the results obtained by the proportional hazards models.

Results

A summary of the results obtained in the study is shown in Table 1. The overall mortality rate up to 180 days of age of live born calves on dairy holdings on the Maltese Islands was found to be 7.08 % (Fig. 1). The mortality rates on the 162 holdings in the

study varied significantly from a minimum of 0.00 % to a maximum of 24.80 %. The number of reported deaths reaches its peak during the first 30 days of age of the calves and then it decreases progressively until 180 days of age (Fig. 2). The median age at death was 52 days and the mean was 63.43 days (SD 45.96). Twenty-five per cent of the calves were reported dead by 25 days of age and 75 % died before reaching 96 days old.

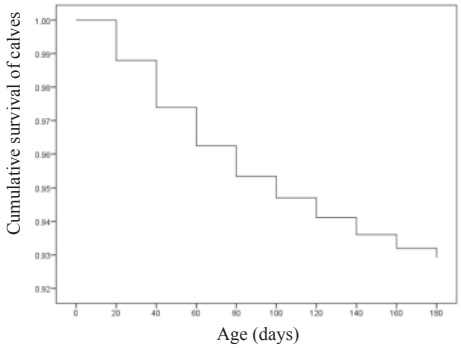

Fig. 1. Cumulative survival curve for calves on dairy holdings on the Maltese Islands starting from day of birth to 180 days of age

The daily hazard rate increased from day 1 to reach a peak of 0.0010 at 15 days of age. It then decreased to peak again at 0.0010 on day 44. The daily hazard rate then decreased gradually until 180 days of age (Fig. 3). The results obtained when the risk factors were analysed are summarised by the Kaplan-Meier curves shown in Figs. 4-7.

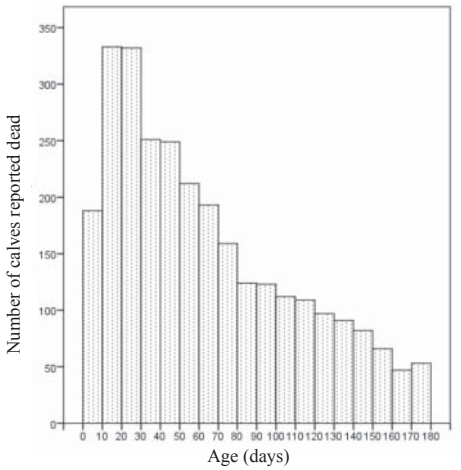

Fig. 2. Histogram showing the distribution of reported deaths in calves by age in days from the day of birth up to 180 days

When the mortality rates on the islands of Malta and Gozo were analysed separately, a value of 6.05 % was obtained for calves on holdings on Malta and 8.80 % for those on Gozo (Fig. 4). Cox Regression analysis demonstrated that the cumulative survival probability of calves on Malta was significantly different from that on Gozo (P<0.001; Exp (B) 0.675; 95 % CI for Exp (B) 0.626-0.729). The risk of a calf dying before reaching 180 days of age is reduced by an estimated 32.50 % on holdings on Malta compared to Gozo.

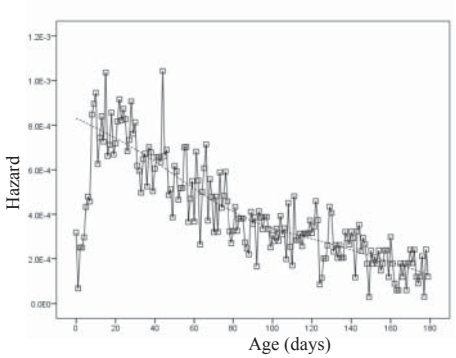

Fig. 3. Line diagram showing the daily hazard of death in calves from birth to 180 days of age. The dotted line is a Lowess smoothed curve generated from the data

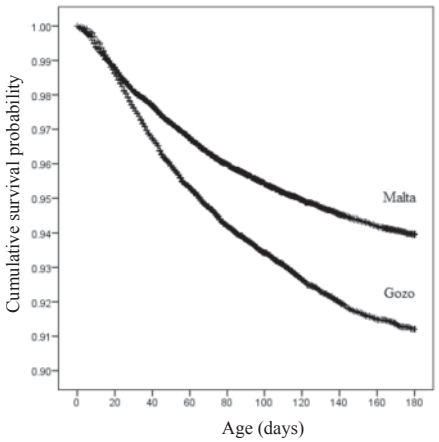

Fig. 4. Kaplan-Meier curves showing the cumulative survival probability of calves from day of birth to 180 days of age on dairy holdings on the Maltese Islands stratified by the island of birth of the calves

Of the 44,078 calves entered in the study, 21,136 were male and 22,942 female. The number of calves reported dead before reaching 180 days of age was 1,482 males and 1,339 females. The cumulative proportion of calves surviving up to 180 days of age is 0.915 (8.50 % mortality rate) for males and 0.940 (6.00 % mortality rate) for females. The Kaplan-Meier curves indicate a difference in the survival probability of male and female calves (Fig. 5). Cox Regression analysis demonstrated that these values were significantly different (P<0.001; Exp (B) 1.413; 95 % CI for Exp (B) 1.312-1.522). A male calf on the Maltese Islands is estimated to have a 41.30 % higher risk of death before reaching 180 days of age than a female calf.

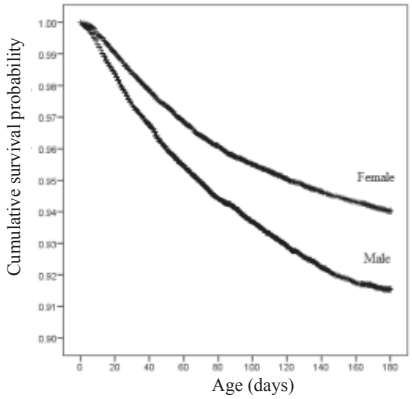

Fig. 5. Kaplan-Meier curves showing the cumulative survival probability of calves from day of birth to 180 days of age on dairy holdings on the Maltese Islands stratified by sex of the calf

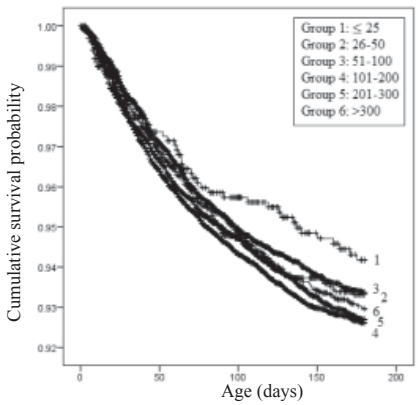

Fig. 6. Kaplan-Meier curves showing the cumulative survival probability of calves on the Maltese Islands stratified by average herd size

When the effect of the average herd size of the holding on calf mortality was analysed by Cox Regression analysis, a significance of P = 0.01 (Table 1) was obtained. The mortality rates were significantly higher in Groups 4, 5 and 6, having an average herd size of 101 - 200 bovines, 201 - 300 and greater than 300 bovines respectively. The Kaplan-Meier curves indicated that from 60 days of age onwards, the mortality rate for calves on holdings having an average herd size of ≤25 is lower than all the other dairy holdings (Fig. 6).

Table 1. Risk factors, number of live births, deaths and mortality rates of calves up to 180 days of age included in the study together with significance values and exponentiation of the B coefficient, Exp (B) values for the various risk factors

Risk factor		Live births (n)	Deaths (n)	Mortality rate (%)	P	Exp (B)	95 % CI for Exp (B)
Island of birth					<0.001		
	Malta	28,848	1,519	6.05		0.675	0.626-0.729
	Gozo	15,230	1,302	8.80			
Sex of calf					<0.001		
	Male	21,136	1,482	8.50		1.413	1.312-1.522
	Female	22,942	1,339	6.00			
Average herd size					0.010		
	≤25	1,000	51	5.85	0.868	1.025	0.764-1.376
	26-50	2,097	116	6.73	0.309	1.114	0.905-1.372
	51-100	10,439	617	6.63	0.167	1.094	0.963-1.244
	101-200	14,066	934	7.39	0.003	1.199	1.065-1.350
	201-300	10,581	697	7.30	0.001	1.239	1.092-1.406
	>300	5,895	406	7.04			
Year of birth					<0.001		
	2004	6,436	371	6.42	0.131	1.130	0.964-1.323
	2005	6,287	460	8.28	0.000	1.455	1.251-1.694
	2006	5,921	425	8.15	0.000	1.423	1.220-1.660
	2007	5,790	347	6.43	0.259	1.097	0.934-1.288
	2008	4,948	377	8.17	0.000	1.413	1.207-1.654
	2009	4,808	294	6.78	0.056	1.176	0.996-1.389
	2010	4,799	284	6.44	0.160	1.128	0.954-1.334
	2011	5,089	263	5.77			
Season of birth					NS		
	Spring	9,848	629	7.04			
	Summer	11,660	731	7.00			
	Autumn	11,250	730	7.16			
	Winter	11,320	731	7.12			

The Kaplan-Meier curves also demonstrated that there was a significant difference between the mortality rates registered in 2005, 2006 and 2008 and the rest of the study period (Fig. 7) and Cox Regression analysis gave a P value of <0.001. The highest mortality rates were registered in 2005, 2006 and 2008, with values of 8.28 %, 8.15 % and 8.17 % respectively. The general trend showed a decrease in the mortality rate over the years, with the lowest mortality rates of 6.78 %, 6.44 % and 5.77 % being registered in 2009, 2010 and 2011 respectively. When the analysis was adjusted for island of birth and the sex of the calves, the resulting trends were similar.

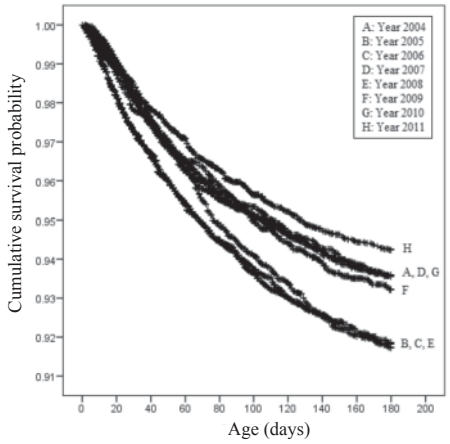

Fig. 7. Kaplan-Meier curves showing the cumulative survival probability of calves from day of birth to 180 days of age on dairy holdings on the Maltese Islands stratified for the year of birth

Mortality rates were not affected by season (P = 0.962), indicating that there is no significant difference in the mortality rates of calves born during the different seasons. The difference is also not significant when adjusted for the islands of Malta and Gozo. Kaplan-Meier curves suggest that for calves born during spring, the mortality rate is slightly lower for the first 60 days of age. However, mortality rates for calves over 60 days of age are very similar whichever season they were born in.

Discussion

Reported calf mortality rates vary widely depending on many factors, some of which may be specific to the particular population being studied. This paper offers a benchmark for the mortality rates up to 180 days of age of live born calves on dairy holdings on the Maltese Islands, and is based on a study of the entire dairy population on the two islands. Furthermore, five risk factors were investigated.

To the best of our knowledge no studies on calf mortality rates on the Maltese Islands have been published. In an unpublished Doctoral thesis entitled 'Assessment of the impact of EU accession on the livestock industries in Malta' VELLA De BRINCAT (2002) reports an estimated average calf mortality rate of 12 % during 2002, whereas in another unpublished Doctoral thesis entitled 'Improvement of quality and quantity of dairy milk in the Maltese Islands' AZZOPARDI (2006) reports an estimated 10-15 % mortality rate in calves within the first month of age during 2005. Most (89.14 %) of the calves in the study belonged to the Holstein Friesian breed, and all the bovine holdings were managed as intensive production systems.

The overall mortality rate of live born calves up to 180 days of age on dairy holdings was found to be 7.08 %. This value is very similar to the 7.00 % reported by AGERHOLM et al. (1993) in Denmark, which however also included stillbirths. Furthermore, the median age at death reported in this study is very similar to the 50-day median age at death reported by SVENSSON et al. (2006) in Swedish dairy calves.

The daily hazard rate found in this study, with peaks at 15 and 44 days of age, is slightly different from that described by AZIZZADEH et al. (2012) where the highest daily probability of death in Iranian Holstein dairy herds was greatest from the day of birth to 20 days of age, after which it decreased markedly. This may be due to the fact that some of the calves dying a few days after birth on the Maltese Islands may not have been tagged yet and as a result would not show up on the NLD.

Under current Maltese legislation, births of calves have to be registered within 7 days of birth, and they have to be ear tagged within 20 days of birth (Government of Malta, 2005a). As a result, calves that died on the holding in the first few days after being born may not have been reported and would not be registered in the NLD. Hence, calf mortality rates for the first 20 days of age reported in this study may be under-estimated. The degree of under-estimation is difficult to determine since no other source of notification and registration is present. This has also been reported by BRICKELL et al. (2009) in a study carried out in England.

In some studies on calf mortality rates, stillbirths were also included in the study (AGERHOLM et al., 1993) leading to a higher mortality rate being reported. This was not possible in this study since stillbirths could not be identified and as a result are not registered in the NLD. This may lead to an underestimation of calf mortality rates.

The highest monthly mortality rate of 2.00 % was recorded for the first 30 days. The monthly mortality rates then decreased progressively with age, reaching a low of 0.46 % at 5-6 months. The relatively high mortality rate within the first month of age seen in this study has also been reported in studies carried out in the USA (JENNY et al., 1981), Denmark (AGERHOLM et al., 1993) and Sweden (SVENNSON et al., 2006).

Differences in mortality rates in male and female calves have already been reported by a number of authors, with male calves having a higher mortality rate than females. CHORE et al. (1998) reported 14.40 % mortality in male calves and 11.14 % mortality in female calves in India. BLEUL (2011) reported that the mortality rate up to 120 days of age for the Holstein breed in Switzerland was 6.70 % and 4.70 % for male and female calves respectively. The mortality rate for female calves on the Maltese Islands is very similar to that found in another study in the UK, where a mortality rate of 6.80 % was reported in female Holstein Friesian calves born alive, during the first 6 months of life (BRICKELL et al., 2009).

Lower mortality rates on smaller holdings have been reported by HARTMAN et al. (1974) in New York dairy farms, and by GULLIKSEN et al. (2009) in Norwegian dairy herds. On the other hand, JENNY et al. (1981) reported a decrease in calf mortality with increasing herd size in dairy herds in South Carolina, whereas JAMES et al. (1984) found no correlation in dairy herds in Virginia. The fact that the lowest overall mortality rate on the Maltese Islands was registered on dairy holdings with the smallest average herd size (≤25) might be due to the fact that since these holdings tend to be family run, calves may be looked after with greater care, resulting in a lower calf mortality rate. In fact, JENNY et al. (1981) reported that when the owner or his immediate family was responsible for the rearing of calves, the mortality rate was lower. Larger farms may also have more calves within the age associated risk period, leading to higher mortality rates.

Calf mortalities were also analysed according to the year of birth of the calves, to verify if there were any changes in mortality rates during the 8-year study period. Following EU accession in 2004, direct financial support was given to the dairy sector, resulting in the restructuring and upgrading of a number of dairy holdings (Ministry for Sustainable Development, the Environment and Climate Change, 2013). The modernisation of the holdings on both islands, together with better management, may have led to the gradual decrease in calf mortality rates, especially during the last 3 years of the study.

A number of studies have taken into consideration the effect of the season of birth on calf mortality. MARTIN et al. (1975) reported that calves born during periods of extreme temperatures in USA had a higher risk of death than calves born during temperate days. GULLIKSEN et al. (2009) reported that calves born in winter in Norway were more likely to die compared to calves born in summer. On the other hand AZIZZADEH et al. (2012) reported a higher risk of calf mortality in Iranian Holstein dairy herds in summer and that this was most likely due to differences in average ambient temperatures. To verify if similar trends are present on the Maltese Islands, stratification by season of birth was carried out. No significant differences were found between the different seasons in this study. This may be due to the relatively mild climate present on the Maltese Islands. During the period under study, the air temperature varied from an average minimum of

12.7 °C in February to an average maximum of 26.9 °C in August (National Statistics Office, Malta, 2012).

The calf mortality rates on dairy farms reported in this study are similar to those reported by some authors in other countries (AGERHOLM et al., 1993; SVENSSON et al., 2006; BRICKELL et al., 2009; AZIZZADEH et al., 2012). Mortality rates on the Island of Malta were found to be significantly lower than those on Gozo. Further study is needed to identify if this is due to management, herd or environmental factors. It was not possible to include certain possible confounding factors such as the presence of dystocia, twin births, failure of passive transfer etc. since no data were available regarding such factors. This could be a limitation of this study since these factors may influence mortality rates, especially during the first few weeks of life of the calves.

Conclusions

The use of the NLD to estimate calf mortality rates on the Maltese Islands shows how this database can be used for research and not only for data collection. This information may be used to address further research towards identifying some of the reasons for the differences reported in this study. This could lead to the lowering of calf mortality rates, thus ensuring a more efficient and profitable dairy sector on the islands of Malta and Gozo.

Conflict of interest statement

No source of funding was made use of in this study. Furthermore, none of the authors have any personal relationships with people or organizations that could inappropriately influence or bias the content of the paper.

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SAŽETAK

Cilj ovog istraživanja bio je utvrditi ukupne stope smrtnosti do 180. dana u živorođene teladi mliječnih goveda, uzgajanih na otocima Malta i Gozo. Istraženo je i pet čimbenika rizika: otok rođenja, spol teleta, prosječna veličina stada te godina i sezona teljenja. Skup podataka uključivao je ukupno 44 078 teladi, oteljene između 1. siječnja 2004. i 31. prosinca 2011. godine u svim stadima mliječnih goveda s oba otoka. Od navedenog broja 28 848 oteljeno je na Malti, a 15 230 na otoku Gozo. Ukupno 2 821 tele uginulo je prije postizanja dobi od 180 dana, što čini ukupnu stopu mortaliteta od 7,08 %. Na otoku Malta ukupna stopa smrtnosti bila je 6,05 %, a na otoku Gozo 8,80 % (P<0,001). Ukupna stopa smrtnosti za mušku telad bila je 8,48 %, a za žensku telad 5,99 % (P<0,001). Držaoci goveda s nižom prosječnom veličinom stada imali su značajno nižu stopu smrtnosti teladi (P = 0,01), što nije bilo kada se u obzir uzela sezona teljenja. Značajna razlika (P<0,001) utvrđena je kada se smrtnost teladi razvrstala prema godini teljenja, pri čemu je smrtnost u posljednje 3 godine istraživanja manja u odnosu na smrtnost u prvih 5 godina istraživanja. Istraživanje je važno s obzirom na prvi opis stope mortaliteta i čimbenika rizika u teladi s otoka Malta i otoka Gozo.

Ključne riječi: telad, mliječna goveda, Gozo, Malta, stopa mortaliteta, čimbenici rizika