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# The Season and Decade of Birth Affect Dairy Cow Longevity

**Pablo Ernesto Bobadilla [1,*], Nicolás López-Villalobos [2], Fernando Sotelo [3] and Juan Pablo Damián [4,5,*]**

[1] Departamento de Salud Publica Veterinaria, Facultad de Veterinaria, Universidad de la Republica, Ruta 8 km 18, Montevideo 13000, Uruguay
[2] School of Agriculture & Environment, Massey University, Palmerston North 4442, New Zealand
[3] Instituto Nacional para el Control y Mejoramiento Lechero, Nueva York 1673, Montevideo 11800, Uruguay
[4] Departamento de Biociencias Veterinarias, Facultad de Veterinaria, Universidad de la Republica, Ruta 8 km 18, Montevideo 13000, Uruguay
[5] Nucleo de Bienestar Animal, Facultad de Veterinaria, Universidad de la Republica, Ruta 8 km 18, Montevideo 13000, Uruguay
* Correspondence: pablo.bobadilla@fvet.edu.uy (P.E.B.); jpdamian@gmail.com (J.P.D.)

**Abstract:** Dairy cow longevity is associated with three key areas: animal welfare, the economy, and the environment. In pastoral dairy systems, cows are exposed to environmental hardships and variations in feed supply associated with the seasonal growth of pastures. The objectives of this study were to generate base parameters for longevity and evaluate the effect of season and decade of birth on herd life (HL) and length of productive life (LPL) for dairy cows in pasture-based production. Records from the Dairy Herd Improvement Database at the Instituto Nacional para el Control y Mejoramiento Lechero (Uruguay) were extracted. The dataset contained 313,146 cows born between 1 January 2000 and 31 December 2019, classified by decade and season of birth. HL and LPL were calculated for each cow. The effects of season of birth, decade of birth, and the interaction between them on HL and LPL were evaluated using a generalized mixed model. The mean HL was 73.4 and mean LPL was 42.0 months. Cows born in spring had longer LPL and HL ($p < 0.001$). Cows born in the 2010s had significantly shorter HL (12.8 months) and LPL (9.14 months) ($p < 0.001$). In conclusion, the season and decade of birth have an impact on the longevity of cows in pastoral-based systems. This study is the first to demonstrate the effect of season of birth on long-term longevity.

**Keywords:** herd life; length of productive life; pasture-based production

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## 1. Introduction

Dairy cow longevity is associated with three key performance areas of the dairy business: animal welfare, the economy, and the environment [1,2]. For instance, longer longevity serves as a reliable indicator of the animal's health and biological functioning, thereby reflecting its welfare [2,3]. Moreover, in relation to longevity, an optimized length of herd life allows for cost recovery of heifer rearing [4] and reduces the replacement rate, thereby diminishing emissions from farms [1,5], which contributes to mitigating global warming and the greenhouse effect. Several factors influence longevity, including the cow's genetic ability to produce milk and survive in different management systems (probability of disease) as well as the farmer's culling decisions [6]. Factors such as productive and reproductive performance, health, replacement (heifer) availability, and milk price influence the farmer's decision to cull a cow [1,7,8]. Pasture-based systems (outdoor) are significantly influenced by weather conditions compared to indoor systems. There are remarkable differences between seasons; during dry and hot summers, cows may experience heat stress, while in winter, mud, humidity, and pathway conditions can have negative effects on the animals [9–11]. Additionally, the season of birth has an impact on feed availability due to the seasonality of pasture growth [12] and environmental conditions, which, in turn, could affect the health of cows and calves, milk yield, animal welfare, and ultimately, cow longevity. Although research primarily focuses on the influence of the season of birth on early-life effects, such as calf weight gain and first lactation performance in heifers, little is known about the influence of the season on long-term aspects like longevity, particularly in pasture-based systems.

Longevity and milk yield have undergone inverse changes over the past few decades. The length of productive life (LPL) has decreased [1], with a range of decrease between 0.9 and 3.04 years in most top milk-producing countries, while milk yield has increased within a range of 18.5 to 129.7 kg per animal per year over the same period [8]. The increase in individual milk yield is more moderate in countries where production is pasture-based [8], but information on longevity or related metrics primarily originates from non-pasture-based systems, with the exception of works like those of Cedeño and Vargas [13] in Costa Rica regarding longevity and breed. Pastoral systems predominantly exist in areas with temperate weather. In South America, countries like Uruguay, Argentina, and Chile predominantly have pasture-based dairy systems with low stocking rates [12]. In the case of Uruguay, total milk production rose from 1329 to 2205 million liters per year between 2000 and 2020, with a consistent number of dairy cows, albeit the number of farms decreased [14,15]. However, to our knowledge, information on longevity and its evolution over time in the scientific literature is scarce at the farm level for these productive systems and the region.

The objectives of this study were to generate base parameters for longevity and evaluate the effect of the season of birth on HL and LPL in dairy cows in the temperate climate pasture-based production system of Uruguay, and to compare how longevity metrics changed in the first two decades of the 21st century. It was hypothesized that the season of birth had an effect on longevity, and that longevity had decreased over time (decade change).

## 2. Materials and Methods

### *2.1. Data*

Data records were extracted from the Dairy Herd Improvement Database at the Instituto Nacional para el Control y Mejoramiento Lechero Uruguay. This is a database with information on health, reproduction, production, milk quality, and management of dairy farms. Information is voluntarily uploaded by associated farmers, farm technicians, and milk quality laboratory technicians.

Available information, such as date of birth, date of first calving, and culling (or death) date, was used to calculate HL and LPL. HL was defined as the number of months between birth and culling or death, while LPL was defined as the number of months between first calving and culling or death, as proposed by Schuster et al. [1].

### *2.2. Inclusion Criteria*

To select the animals for this study, the following criteria were followed:

- All the farms considered were pasture-based dairy farms;
- Cows born between 1 January 2000 and 31 December 2019 were selected;
- A minimum of one hundred cows per herd was required for a herd to be selected;
- Restriction intervals were defined: cows with HL greater than 20 years and cows with age at first calving (AFC) under 20 months and over 48 months were excluded;
- No cows culled before calving were considered;
- The end of the study period was 1 July 2022. Cows were considered censored observations when no updated information was available between the last recorded event and the end of the study period. “Active cows” at the end of the study period for which a culling or death date was not available were only considered and used as censored observations for survival analysis.

The inclusion criteria resulted in the following number of observations: 313,146 individual cows from 367 dairy farms were selected (a mean of 853 cows per farm, median of 490 cows per farm). Both cows that had already been culled and those that were still active in the database were considered. Of these, 93% of the cows were purebred Holstein, while the remaining were purebred Jersey and crossbreeds.

Of the final number of observations, 249,441 had already been culled (or dead) by the end of the study period, and 63,705 were still alive (censored observations).

Two categorical variables were created: season and decade of birth. Four seasons were considered: summer (December to February), autumn (March to May), winter (June to August), and spring (September to November). Two decades were also considered: the 2000s (1 January 2000 to 31 December 2009) and the 2010s (1 January 2010 to 31 December 2019).

Due to the fact that part of the cows born in the 2000s were still active in the 2010s and to prevent a bias towards HL and LPL values when comparing decades, for every statistical analysis that required comparing cows between the 2000s and the 2010s, only cows with an HL equal to or under 120 months in the database were considered.

### *2.3. Statistical Analysis*

#### 2.3.1. Descriptive Analysis

- Mean and median values for HL and LPL were calculated considering the 249,441 already culled cows born between 1 January 2000 and 31 December 2019;
- The number of births per month and season was calculated considering the overall period and both decades separately;
- Density plots for HL and LPL were constructed for each decade.

#### 2.3.2. Inferential Analysis

A generalized linear mixed model for 233,826 cows with an HL equal to or under 120 months and for those that had already been culled was fitted to evaluate season and decade of birth as explanatory variables and the farm as a random effect:

$$\gamma_{ijk} = \mu + S_i + D_j + (S_i \times D_j) + \upsilon_k + \varepsilon_{ijk}$$

where:

$\gamma_{ijk}$ = response variables herd life (HL) and length of productive life (LPL);
$\mu$ = population mean;
$S_i$ = ith fixed effect of the season of birth (four classes: autumn, winter, spring, summer);
$D_j$ = jth fixed effect of the decade of birth (two classes: 2000s and 2010s);
$(S_i \times D_j)$ = fixed effect of the ijth interaction between season and decade of birth ($4 \times 2 = 8$ classes);
$\upsilon_k$ = random effect of the kth herd (367 herds);
$\varepsilon_{ijk}$ = random residual error.

Normal distribution was assumed for HL and LPL; an identity link function was used for both models and the Tukey–Kramer test was used to compare between adjusted least-squares means.

Kaplan–Meier survival probability curves for HL and LPL in the 2000–2019 period were plotted for 313,146 cows (249,441 non-censored observations and 63,705 censored observations). Median survival probability times were calculated.

To account for possible bias in the decade comparison due to the follow-up periods of both decades, Kaplan–Meier survival probability curves for HL and LPL comparing the 2000s and 2010s were plotted for 273,318 cows equal to or younger than 120 months of HL (233,826 non-censored observations and 39,492 censored observations). Median survival probability times were calculated.

Log-rank tests were used to compare survival curves.

For all statistical tests, the significance level considered was alpha = 0.05.

### *2.4. Software*

Tidying and filtering of the data were performed using the statistical software R (version is 4.1.2). The following packages were used: "tidyverse" package [16] for data editing and graphics construction, "lubridate" package [17] for date manipulation, "survival" package [18] for survival analysis, "survminer" package [19] to plot survival curves, and "lmerTest" package [20] for the GLMM.

## 3. Results

### *3.1. Longevity Metrics*

#### 3.1.1. Longevity Metrics for the 2000 to 2019 Period

The means and median values for HL and LPL for the study period (2000 to 2019) are presented in Table 1.

**Table 1.** Median ± interquartile range (IQR) and mean ± standard error (SE) for herd life and length of productive life of 249,441 dairy cows that were born from 1 January 2000 and culled before 1 July 2022 in Uruguay.

| Trait | Median ± IQR | Mean ± SE |
|---|---|---|
| Herd life (months) | 69.3 ± 38.1 | 73.4 ± 0.06 |
| Length of productive life (months) | 37.7 ± 37.2 | 42.0 ± 0.05 |

#### 3.1.2. Longevity Metrics and Cows Born by Season of Birth

Season of birth had a significant effect for both metrics considered ($p < 0.001$; Table 2). Cows born in spring had a longer HL, and LPL was higher for spring and autumn (Table 2). The number of cows born changed by season, where the greatest frequency of births occurred in autumn (Table 2).

In Figure 1a, the monthly distribution of births for the 2000–2019 period is shown, where most births occur in autumn, particularly in the month of March. A similar distribution of births can be observed for both decades, when compiled together (Figure 1a) and when considered separately (2000s: Figure 1b; 2010s: Figure 1c).

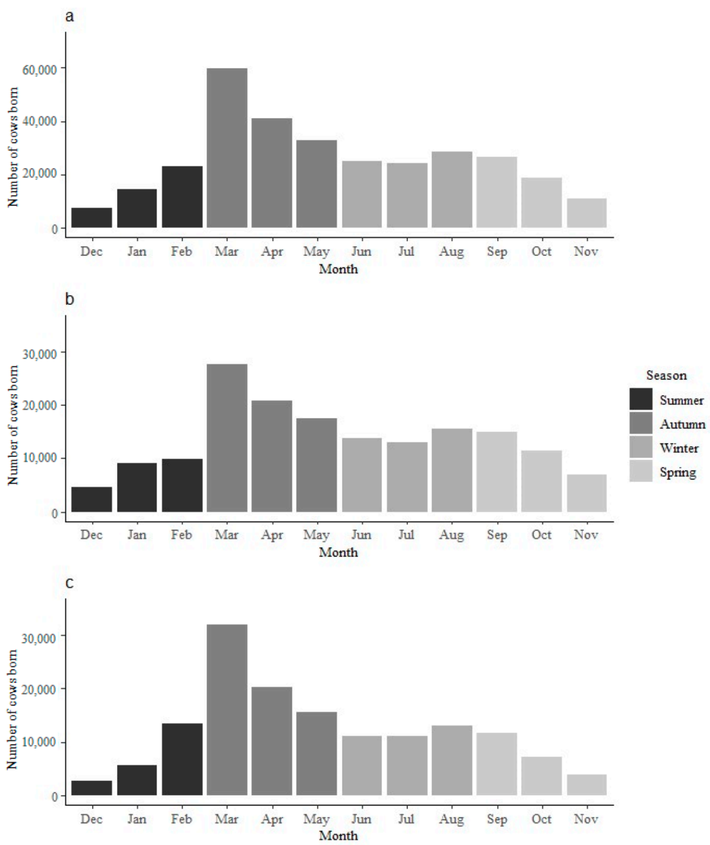


**Figure 1.** Bar plots for number of cows born by season and month for the 2000–2019 (**a**), 2000–2009 (**b**), and 2010–2019 (**c**) periods in Uruguay.

**Table 2.** Mean ± standard error in months for herd life (HL) and length of productive life (LPL) by season of birth of dairy cows in Uruguay.

| Season | N (%) [1] | HL | LPL |
|---|---|---|---|
| Autumn | 99,632 (42.6%) | 67.94 ± 0.068 [c] | 37.51 ± 0.067 [a] |
| Winter | 58,700 (25.1%) | 67.85 ± 0.090 [c] | 36.67 ± 0.089 [b] |
| Spring | 42,309 (18.1%) | 69.10 ± 0.109 [a] | 37.65 ± 0.107 [a] |
| Summer | 33,185 (14.2%) | 68.38 ± 0.119 [b] | 36.70 ± 0.118 [b] |

[1] Percentage of cows born in each season considering the 2000–2019 period. [a], [b] and [c]: means with different superscript letters within the column are significantly different ($p < 0.05$).

### 3.1.3. Longevity Metrics by Decade of Birth

The longevity metrics considered decreased with the change of decade, as shown in Table 3.

Figure 2 presents the distribution of herd life and length of productive life classified by decade of birth. Cows born in the 2000s are on average culled at older ages than the ones born in the following decade, as seen for HL and LPL. Additionally, differences in culling patterns can be observed between the decades in the plots.

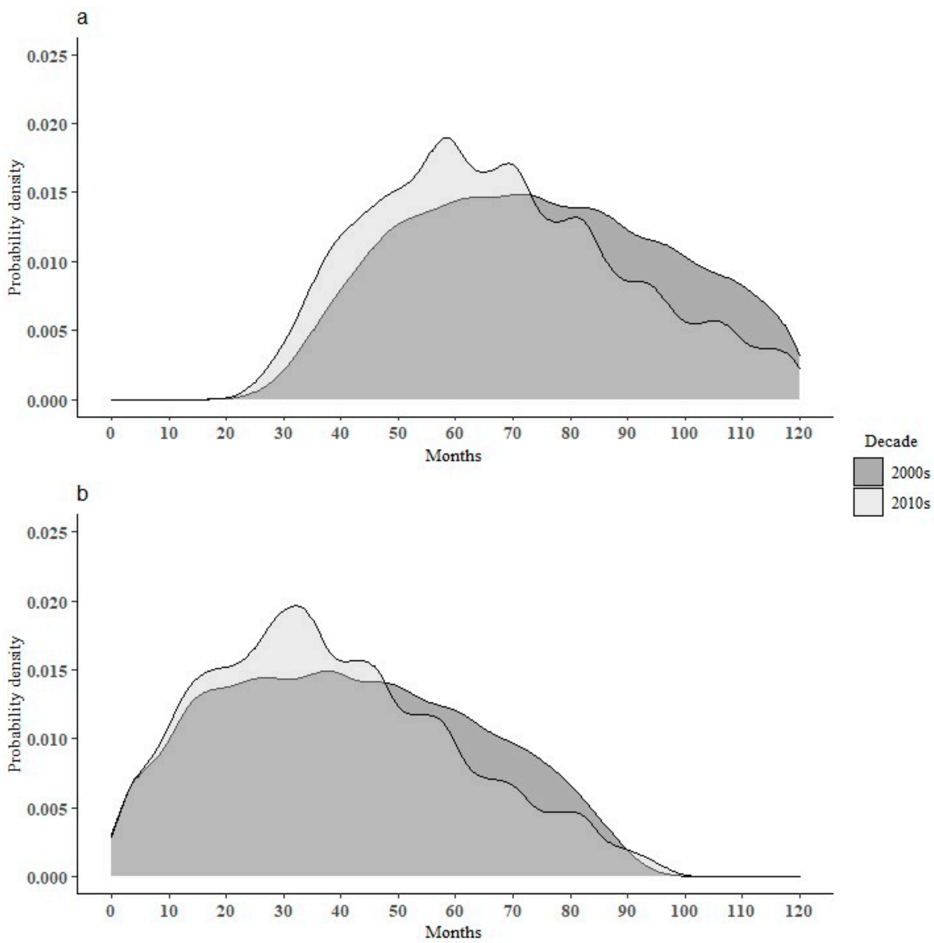


**Figure 2.** Density plots for herd life (**a**) and length productive life (**b**) in months for cows in Uruguay by decade of birth.

**Table 3.** Mean ± standard error in months for herd life and length of productive life by decade of birth of dairy cows in Uruguay.

| Decade | N (%) [1] | Herd Life | Length of Productive Life |
|---|---|---|---|
| 2000s | 135,151 (59%) | 74.72 ± 0.062 [a] | 41.71 ± 0.062 [a] |
| 2010s | 98,675 (41%) | 61.92 ± 0.076 [b] | 32.57 ± 0.075 [b] |

[1] Percentage of cows in each category considering the 2000–2019 period. [a] and [b]: means with different superscript letters within the column are significantly different ($p < 0.001$).

### 3.1.4. Survival Probability Curves for HL and LPL

The Kaplan–Meier survival probability curves for the 2000–2019 period for 313.146 cows (censoring rate = 0.2) are presented in Figure 3a,b. Median values of survival were 77.7 months for HL (Figure 3a) and 46.4 months for LPL (Figure 3b). The mean of censored observations (n = 63.706) was 111.5 (SD = 43.5).

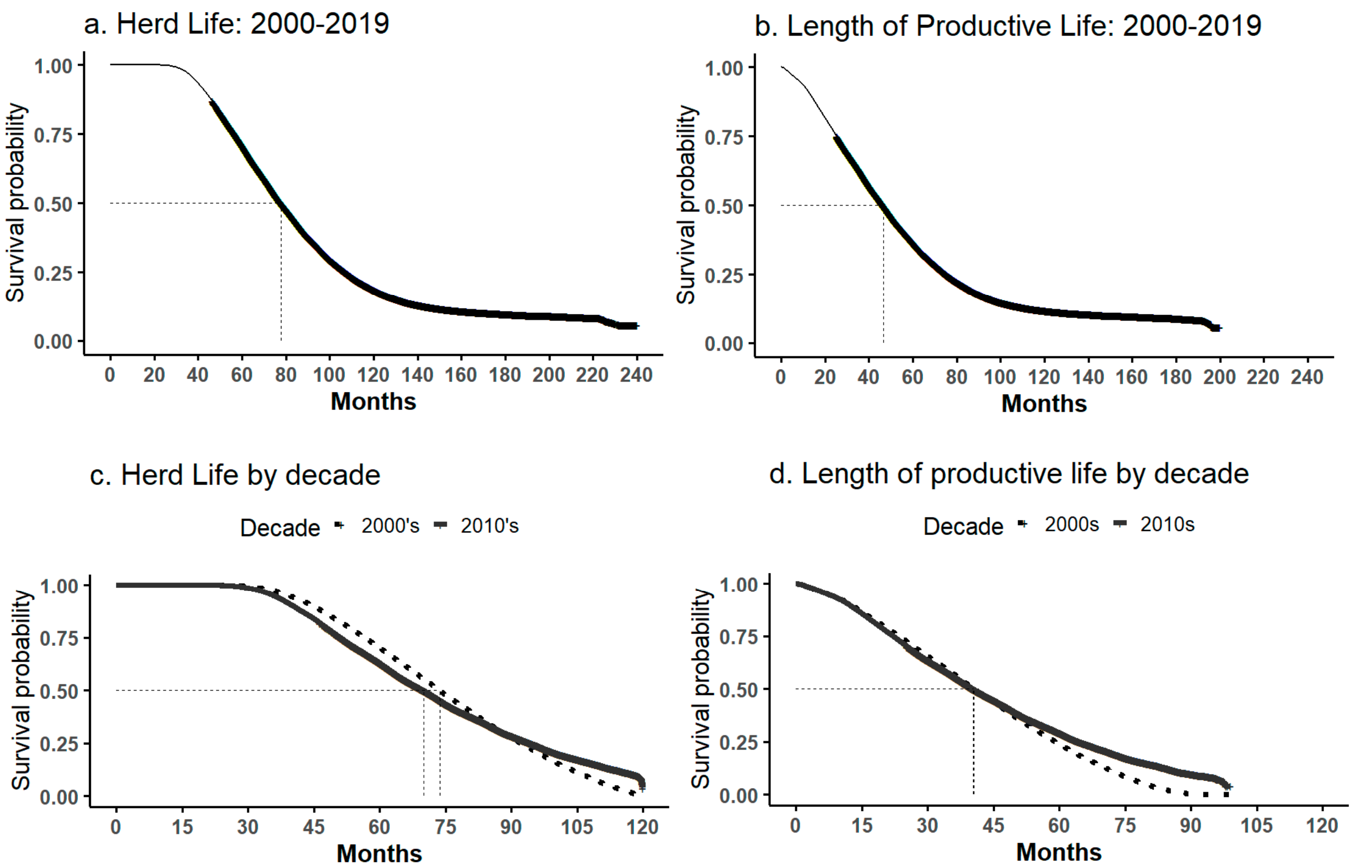


**Figure 3.** Kaplan–Meier curves for survival probability in months for the 2000–2019 period for herd life (**a**) and length of productive life (**b**) of dairy cows in Uruguay. Kaplan–Meier curves for survival probability in months and categorized by decade of birth, dotted line for the 2000s and solid line for the 2010s, for herd life (**c**) and length of productive life (**d**). The thin dotted line represents 0.5 survival probability time for each metric.

Kaplan–Meier survival probability curves considering decade of birth for 273.318 cows (censoring rate = 0.14) equal to or under 120 months of HL are presented in Figure 3c,d. Median survival time (months) for HL was 73.7 in the 2000s and 70.0 in the 2010s (3c); for LPL, it was 40.6 and 40.4, respectively (3.d). For both metrics, significant differences ($p < 0.01$) were found between curves when comparing the decades. Differences between the decades, particularly for older ages, are less consistent than those observed with the GLMM.

Censored observations were only from the 2010s (n = 39,492), with a mean of 81.9 (SD = 18.8).

#### 3.1.5. Interaction between Decade and Season for Longevity Measures

The effects of decade, season of birth, and the interaction between them on HL and LPL were significant ($p < 0.001$). Cows born in the 2000s had on average higher values for every metric considered and for every season when compared with cows born in the following decade (Table 4). For the 2000s, animals born in spring and summer had longer HL and cows born in spring had longer LPL. In the 2010s, cows born in spring had longer HL, and cows born autumn and spring presented higher values for LPL.

**Table 4.** Mean ± standard error in months for herd life (HL) and length of productive life (LPL) by decade and season of birth of dairy cows in Uruguay.

| Decade | Season | N (%) [1] | HL | LPL |
|---|---|---|---|---|
| 2000 | Autumn | 54,159 (40%) | 74.13 ± 0.092 [c] | 41.81 ± 0.091 [b] |
| | Winter | 34,756 (26%) | 74.53 ± 0.115 [bc] | 41.67 ± 0.114 [b] |
| | Spring | 27,151 (20%) | 75.34 ± 0.130 [a] | 42.34 ± 0.129 [a] |
| | Summer | 19,085 (14%) | 74.87 ± 0.155 [ab] | 41.00 ± 0.153 [c] |
| 2010 | Autumn | 45,473 (46%) | 61.76 ± 0.101 [b] | 33.22 ± 0.099 [a] |
| | Winter | 23,944 (24%) | 61.17 ± 0.139 [c] | 31.67 ± 0.137 [c] |
| | Spring | 15,158 (16%) | 62.87 ± 0.174 [a] | 32.97 ± 0.172 [ab] |
| | Summer | 14,100 (14%) | 61.88 ± 0.181 [b] | 32.40 ± 0.179 [b] |

[1] Percentage of cows in each category considering the 2000–2009 and the 2010–2019 periods. [a], [b] and [c]: means with different superscript letters within the column are significantly different ($p < 0.05$).

## 4. Discussion

This study describes for the first time the longevity of dairy cows in a temperate climate pasture-based production system in South America, considering the birth season of the cows and the change of decade during the first two decades of the 21st century. The cows considered in this study showed values of HL and LPL that are more similar to those found in indoor systems than those for pasture-based dairy systems from other countries. For example, Uruguay, with an average LPL of 2.7 years in the 2010s, is within the range of the top ten milk-producing countries for the same decade, where LPL varies from a median of 2 years in Canada to a median of approximately 5 years in New Zealand [8]. It is interesting to highlight that although the milk production system in Uruguay is pasture-based, similar to the pasture-based system of New Zealand, there are large differences in LPL between the two countries. Therefore, similar pasture-based production systems on different continents and with different management styles present differences in the longevity profiles of dairy cows. These results highlight other factors that possibly influence the parameters of longevity in dairy cows and not only the particular consideration of the pasture-based system. Previously published long-term studies estimate longevity metrics from culling rates [8]. In this sense, it is relevant to highlight that the use of high volumes of data from Dairy Herd Improvement Databases to calculate longevity metrics is not easily found in the literature. To our knowledge, it only has been used in the Latin American context by Cedeño and Vargas [13] for LPL and Vargas-Leiton et al. for AFC [21] and, for the first time in South America, in this study for HL and LPL.

The season of birth influenced both longevity metrics for dairy cows. To our knowledge, no studies have evaluated the impact of the season of birth on longevity metrics in pasture-based systems. Previous studies, such as those by Froidmont et al. [22] and Jenko et al. [23], have examined the relationship between longevity and the season of first calving but not specifically the season of birth. Analyzing the period from 2000 to 2019, we found that cows born in spring had the highest values for herd life (HL) and shared the first place with autumn for length of productive life (LPL). The influence of the season of birth on dairy cow longevity in pasture-based systems is intriguing due to its implications for the interplay between environmental changes, pastures, and animals. It is important to consider how the season affects offspring, including potential effects during pregnancy, such as fetal programming [24–26], as well as post-calving effects that impact calf development [27–29]. For instance, heat stress in mothers can affect fetal and neonatal growth, maternal immune function in offspring, and metabolism [26,27,30]. Animals born in spring and summer, when daylight is increasing, tend to be lighter and reach puberty at a younger age compared to those born in autumn and winter [31]. Recent research by Dallago et al. [32] reported that calving conditions, including calving ease, birth size, and twinning, are associated with HL and LPL, indicating that calving conditions also influence offspring longevity. While cows born in spring had longer LPL and HL, it is worth noting that over 60% of births in this production system occurred in autumn and winter, consistent with previous reports by Farina and Chilibroste [12]. Autumn and winter are seasons when feed availability, particularly pasture, is lower [33,34]. Interestingly, although spring had the highest values for HL and the second highest for LPL according to our data, it accounted for only 18.1% of births. Cows calving closer to or during spring have the advantage of greater pasture availability during early lactation, which is when the cow's nutritional requirements are the highest [35,36]. These favorable feeding conditions during spring may have positive effects not only on the cow but also on calf development [37]. Indoor-housed calves are known to be affected by microclimate factors such as air temperature, relative humidity, and wind drafts, which impact the incidence of respiratory and gastrointestinal diseases and mortality rates. In contrast, in the pasture-based system analyzed in our study, rearing is conducted outdoors, exposing even more young animals to weather-related challenges. Previous studies have shown seasonal higher rates of diarrhea and respiratory disease in indoor seasons (autumn–winter) compared to outdoor seasons (spring–summer) [38]. Additionally, calves born in summer have been found to have a lower frequency of enteritis compared to other seasons [39]. The combination of reduced feed availability and adverse climatic conditions during summer and winter may contribute to the observed differences in HL and LPL by season. Given the linkage between longevity, health, animal welfare, and the environment [1,2], as well as the greater longevity observed in cows born in spring, our study underscores the importance of evaluating the effects of birth season on production, reproduction, longevity, and farm profitability to promote more sustainable milk production in Uruguay and similar pasture-based systems.

Cows born in the 2000s exhibited higher means for herd life (HL) and length of productive life (LPL) compared to cows born in the 2010s. This result was evidenced from two different types of analysis: survival and the GLMM. However, the differences in longevity according to the change of decade were of greater magnitude when analyzed using the GLMM than using survival analysis. Regarding this point, it is important to consider the potential bias of the age structure, particularly in the 2010s, associated with the follow-up period of this study. Therefore, when discussing the differences found between the two decades, we prefer to be more cautious, and consider that the results of the survival analysis could show more precise data than those provided by the GLMM. This decline in longevity from the 2000s to the 2010s may be attributed to various factors associated with genetic selection, milk prices, feeding costs, and management. The continuous growth in milk production observed in several countries and regions, including Canada, the United States, the European Union, and Australasian countries [1], is a clear reflection of genetic selection for milk yield, as well as an improvement in environmental conditions. Uruguay, experiencing sustained annual growth in milk production, is no exception to this trend. Alongside genetic improvements, the increase in milk production in Uruguay has been linked to higher stocking rates, milk production per cow, and the milking-to-dry-cow ratio [12]. Although we did not evaluate milk production between both decades in our study, the study by Fariña and Chilibroste [12] carried out in Uruguay and on a large number of dairy farms reaffirms that milk production increased from decade to decade. However, based on our longevity results in the present study and milk production trends according to Fariña and Chilibroste [12], the increase in milk production may probably be inversely associated with longevity. These contrasting changes in milk production and longevity suggest that greater milk production demands may have a negative impact on cow health. The Kaplan–Meier survival curves also supported these findings, revealing a significant reduction in HL and LPL between the assessed decades when incorporating active cows as censored observations in the database. Similarly, Jenko et al. [23] in Slovenia observed that genetic gains were reflected in higher first lactation milk production and lifetime milk production over the period from 1970 to 2000 but not in the length of productive life. Our study shows a negative long-term impact on HL and LPL indicators, potentially resulting in the loss of an entire lactation when both decades are compared. These results raise questions about whether the higher milk production demands, while potentially beneficial in the short term for farmers, could have counterproductive effects in the long term, not only concerning farm economics but also in terms of animal welfare and global warming [1,2]. Uruguay, being a small country heavily reliant on the global economy and international milk prices despite being a top milk producer, experienced fluctuations in milk prices during the 2000–2020 period, including notable drops in 2009 and 2015 [40]. When faced with reduced milk prices, farmers tend to increase herd size and reduce operational costs such as veterinary care or participation in herd management programs [41]. Under such conditions, individual cow health, welfare, and performance may deteriorate, increasing the risk of premature culling and thereby negatively impacting longevity [42]. While our study did not aim to identify the specific causes of the decrease in dairy cow longevity associated with the change of decade, it is conceivable that fluctuations in milk prices may have contributed to this trend. Additionally, intensifying milk production in cows is accompanied by physiological, behavioral, and immune alterations, which can elevate disease risks, further impacting health, welfare, and necessitating early culling [2,43]. Although the average natural life expectancy of milk-producing cows can be around 20 years [2], the LPL of cows has decreased over the decades, reaching just under 3 years in the last decade in Uruguay. Furthermore, differences in age patterns between decades can be observed, with cows culled in the 2010s appearing to be culled at specific moments as suggested by the occurrence of noticeable "peaks" and "valleys" in the density plots for the 2010 decade, whereas cows in the previous decade seem to have been culled more evenly and less concentrated at certain moments in time, suggesting that farmers prefer to cull cows at the end of lactation rather than during the lactation period. Considering the impact of dairy cow longevity on animal welfare, farm economics, and the environment [2,8], and the anticipated global temperature rise [44] with its projected impacts on animal production, particularly in pasture-based systems, longevity should be regarded as a crucial factor in achieving a balance between high production and sustainability in dairy systems.

When analyzing the interaction between season and decade of birth, it is important to note that HL followed the same pattern when decades were examined separately and for the entire period (2000–2019), while for LPL, the highest values were observed in spring during the 2000s and in both spring and autumn during the 2010s. Beyond changes according to season and according to decade in the case of LPL, in general and for both (LPL and HL), spring stands out as a key season associated with greater longevity metrics of dairy cows. It is important to note that our results are based on a large number of data, which, although it is a strength (given the statistical power), precisely the large number of data favors the probability of finding significant differences, even with small numerical differences. It is worth noting that a lactating cow becomes profitable once the debt incurred during rearing is repaid, a period that can extend up to 1.5 lactations [45]. In this sense, and according to management, cows can be born in a season that helps prolong their productive life, improve their well-being conditions, better face environmental challenges, and reduce production costs in pasture-based systems. Births in Uruguay are concentrated in autumn, especially in March, and this concentration is even more pronounced in the 2010s. Further studies are needed to explore the potential causes that could explain the different profiles of the HL and LPL variables. Despite these differences, in terms of LPL, autumn and spring appear to be the most suitable seasons for calving planning. This aligns with the availability and good consumption of pasture during these seasons, as well as the birth of offspring in seasons with moderate climates, avoiding heat stress in summer or rain and mud in winter [12,35]. Hence, although births in Uruguay are predominantly concentrated in autumn (more than 40%), this study provides evidence for the importance of spring as a favorable birth season for the longevity of dairy cows in pasture-based systems.

## 5. Conclusions

The longevity metrics of dairy cows in pasture-based systems are influenced by the season and decade of birth. The highest HL and LPL values were observed in spring for the entire period. When the decades were analyzed separately, HL continued to be higher in spring in both decades, while for LPL, in the 2000s, the highest value was in spring, and during the 2010s, the highest values were in spring and autumn. HL and LPL both decreased from the 2000s to the 2010s. Despite calving being concentrated in autumn in Uruguay, this study provides evidence for the importance of the spring calving season in terms of the longevity of dairy cows in pasture-based systems.

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