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TRENDS IN CALF MORTALITY: A BIBLIOMETRIC OVERVIEW

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Abstract: The main goal of cattle breeding is to maximize profitability through improved production and reproductive performance. In dairy farming, the target is to calve once a year, with the expectation that these calves survive. Calf mortality is not just a problem; it is a major threat to the sustainability of operations and the welfare of animals. It is a key indicator of the overall condition of cattle farms, reflecting their economic, health, and welfare status. Calf mortality refers to the losses occurring from birth up to six months of age, directly affecting the profitability and well-being of the herd. While it is recommended that calf losses do not exceed 5%, reported perinatal mortality rates in cows and calves range from 2% to 20%, with most countries recording rates between 5% and 8%. This study conducted a bibliometric analysis based on data retrieved from the Web of Science (WoS) database to evaluate the scientific literature on calf mortality. The analysis was based on data retrieved from the Web of Science (WoS) database, where a search was performed on titles, keywords, and abstracts. A total of 2359 publications from the period 1945–2025 were identified and analyzed using the bibliometrix package in R software, focusing on citation networks and bibliographic linkages. The findings indicate a growing academic interest in calf mortality recently. Regarding publication types, research articles constituted the majority (2108), followed by conference papers (27), reviews (124), editorial notes (11), book chapters (6) and others (83). While the number of countries conducting scientific research on calf mortality is quite high, the USA (1358), Canada (583), and UK (315) are leading nations in terms of both domestic studies and collaborations with other countries. These results highlight the increasing academic interest in calf mortality and the expanding range of research contributions in this area and may provide practical information for cattle breeders in the field.

Keywords: Cattle, Calf losses, Calf mortality, Bibliometrics

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1. Introduction

Calf mortality has serious consequences for farms, leading to both financial and genetic losses (Lombard et al., 2007; Raboisson et al., 2013; Zhang et al., 2019; Hordofa et al., 2021) as well as negatively impacting animal health and welfare (Barnard, 2015; Ortiz-Pelaez et al., 2008; Roche et al., 2023; Wei et al., 2022). There are numerous causes of calf mortality. However, accurately forecasting these potential causes enables timely, and appropriate interventions which will facilitate the effective implementation of preventive health measures. Therefore, it is essential to first understand the time frame following birth (e.g., the first 24 hours, the first 48 hours, 0-3 months, 4-6 months, etc.) during which losses occur and/or are concentrated, as this knowledge will enhance the chances of timely interventions. Despite a lack of clear information in the literature (Umaña Sedó et al., 2023), a significant portion of calf mortality within the first six months occurs during the perinatal period (the first 48 hours before, during, and after birth). To mitigate mortalities during this critical time, effective management practices including the calving process, colostrum management, calf housing, feeding management, hygiene, and pathogen control are imperative (Nielsen et al., 2010; Costa et al., 2015; Urie et al., 2018; Sedó et al., 2024).

Moreover, understanding the causes and risk factors associated with calf losses is vital for implementing effective on-farm measures and improving overall animal health and welfare. Studies on calf mortality indicate considerable variability both between countries and among different herds within the same country. For instance, Sweden and Norway reported low mortality rates during the first month post-birth at 1.2% and 1.5%, respectively (Simensen, 1982; Olsson et al., 1993), while significantly higher rates were documented in Denmark, France, and the United States (Wells et al., 1996; Fourichon et al., 2001; Vaarst and Sørensen, 2009; Nielsen et al., 2010). A study conducted on a dairy farm in the western United States indicated a mortality rate of

approximately 2%. In Canada, Windeyer et al. (2014) noted that around 16% of calves (4-51 days old) faced diarrhea during the first 28 days, with 7% (1-87 days) suffering from severe diarrhea; extended days of diarrhea correlated with increased mortality risk. Furthermore, Urie et al. (2018) reported a pre-weaning calf disease rate of 33.9%, with a mortality rate of 5.0%. These findings underscore the necessity for producers to adopt improved colostrum management practices. Umaña Sedó et al. (2023) determined in a comprehensive study that pre-weaning calf mortality rates ranged from 5 to 11% and perinatal mortality rates ranged from 2 to 10%. However, the comparison of these rates is complicated by insufficient record-keeping, variations in data collection methods, and inconsistencies in calculations and definitions.

Calf mortality arises from a complex interplay of factors that cannot be attributed to a single cause. In this context, bibliometric analysis provides a varied and comprehensive perspective for determining the scope of the subject. Calf mortality, which significantly impacts the future of the herd, has been studied less frequently compared to issues such as reproduction and nutrition within the cattle industry. This study aims to systematically and transparently examine existing research through bibliometric analysis, with the objective of providing detailed insights into calf mortality, the main factors influencing it, and the relationships among these factors.

2. Materials and Methods

2.1. Data Analysis

Before commencing the bibliometric analysis, it is crucial to have a clear understanding of the topic at hand. Specifically, the research subject should be accurately filtered, and key components relevant to the study must be selected. Therefore, elements such as the research timeframe, field and subfield, language, and types of documents to be included should be defined before conducting database searches. In this study, the Web of Science, one of the largest article databases globally, was utilized to identify calf losses and the major factors that may influence them.

Scientific research examining calf mortality, and its potential major influences has been evaluated through bibliometric analysis using the flowchart presented in Figure 1. As illustrated in the figure, the flowchart of bibliometric analysis consists of several stages, including data collection, preprocessing, network extraction, normalization, mapping, and analysis.

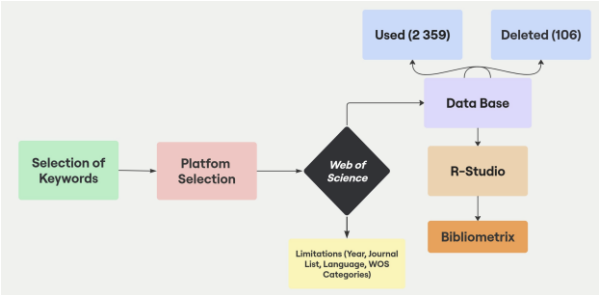


Figure 1. Strategy and workflow diagram for bibliometric analysis of calf mortality.

After selecting the database, the next step involved identifying representative keywords related to the research theme. This study aimed to identify works focusing on calf mortality and major factors affecting these losses; thus, specific keywords were compiled, and certain constraints were added to avoid deviations from the topic. Therefore, the keywords for searching scholarly databases included terms such as 'dairy', 'beef', 'calf*', 'mortality', 'losses', 'stillbirth', 'death', 'perinatal', 'health', 'dystocia', 'colostrum', 'calving season' and 'housing'. To enhance the accuracy of the search, several search operations were conducted using 'asterisks' to account for both singular and plural forms of terms. Additionally, to avoid repetition of terms within the search sets, 'parentheses', 'and', and 'or' terms were employed.

Once the keywords were established, constraints were imposed on the journals from which the research could be drawn, again to prevent deviations from the topic. The data selection and organization procedure was advanced through the review of the obtained information. After scanning the database, a total of 2465 documents were found. These documents consisted of book chapters, conference materials, review articles, and editorials. Some repetitive and irrelevant works were excluded (47). Studies that were deemed unrelated to the theme, despite containing some of the key terms related to this research, such as cow, dairy, beef, etc., were removed because the expressions only appeared randomly within them. After thorough filtering, 2359 documents were reviewed. Table 1 presents the distribution of these studies by type of scientific document.

An examination of Table 1 reveals that the majority (89.3%) of the scientific publications consist of original research articles. This is followed by review articles (5.3%), proceeding papers (1.4%), article-proceeding papers (1.4%), and meeting abstracts (1.1%). The remaining proportion, approximately 1.4%, is composed of other types of scientific documents.

Table 1. Distribution of studies according to scientific document types

Type of Scientific Document	Frequency
Article	2106
Article; Book Chapter	6
Article; Early Access	2
Article; Proceedings Paper	34
Correction	4
Editorial Material	11
Meeting Abstract	27
News Item	1
Note	10
Proceedings Paper	34
Review	124
Total	2359

2.2. Bibliometric Mapping and Clustering

The documents obtained from the WOS database were analyzed using the "bibliometrix" package (version 4.1.3) in R software (version 4.5.0) (R Development Core Team, 2025). The bibliometrix package is a free R library developed for bibliometric analyses of scientific publications, including the evaluation of citations (Aria and Cuccurullo, 2017). With this library, both quantitative and qualitative analyses of bibliographic data were conducted; furthermore, patterns and trends in the scientific output of the analyzed articles were identified. Bibliometrix enables the assessment of scientific production across different fields of knowledge, the definition of primary research areas, and the tracking of the evolution of scientific knowledge over time. Additionally, "biblioshiny", an extension of the bibliometrix package, was also utilized.

3. Results

3.1. Descriptive Analysis

The descriptive information derived from the bibliometric analysis conducted based on the selected criteria is presented in Table 2.

Table 2. Descriptive information for the documents

Description	Results
Timespan	1945:2025
Sources (Journals, Books, etc.)	251
Documents	2359
Annual Growth Rate, %	4.3
Average Years from Publication	29.13
Average Citations per Documents	23.05
References	4227
Keywords Plus	3107
Author's Keywords	3391
Authors	6956
Single-Authored Documents	181
Documents per Author	0.34
Author per Document	1.57
Co-Authors per Document	4.63

A total of 2359 scientific documents related to calf mortality and its potential major influences, published between 1945 and 2025, were identified, with an annual publication growth rate of 4.3% between 1945 and 2024 (Table 2). These articles originate from 251 different sources, involve a total of 6956 authors, and include 147 articles written by a single author. On average, there are 4.63 authors per document. Additionally, analyses indicate that the average citation count per document is 23.05, and the articles collectively referenced 42227 scientific works. Approximately 90% of these studies are categorized as articles, 5.3% as reviews, while the remainder consists of book chapters, conference proceedings, meeting notes, etc. Figure 2 provides a visual representation of the temporal evolution of these publications.

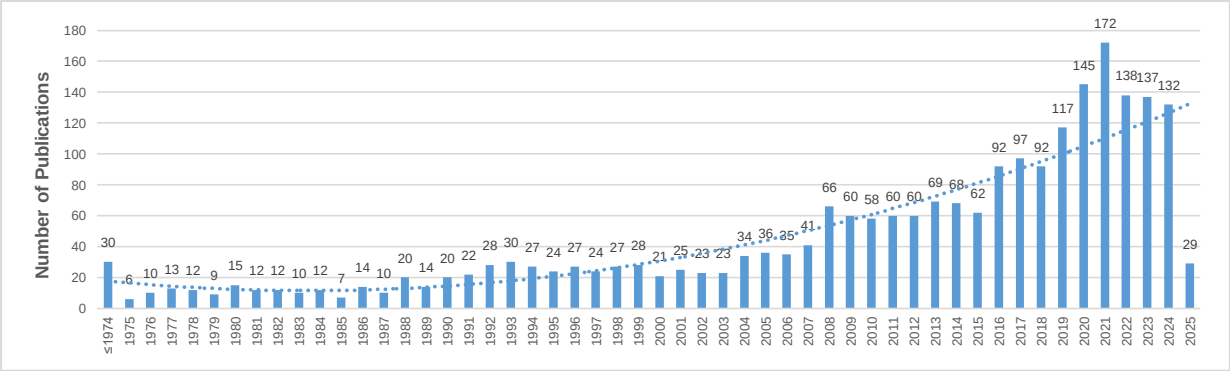


Figure 2. Number of publications from 1945 to 2025.

Figure 2 indicates that the number of publications in this field has increased in recent years. Notably, there was a sharp rise in the number of publications after 2018, reaching its peak in 2021 with a total of 172 publications. Following 2021, although there has been a slight decline in the number of publications, it can be observed that interest in this topic remains persistent.

3.2. Authors

A total of 6,956 authors have contributed to 2,359 publications related to calf losses and their major influencing factors. Detailed information regarding the 10 most productive authors in this field is given in Figure 3. As illustrated in Figure 3, Dave L. Renaud emerges as the most productive author, having published 61 articles (2.6%) in this area, followed by Emily K. Miler-Cushon (30 publications) and Donagh P. Berry (28 publications). Figure 3(b) displays the h-indices of these top 10 authors, a widely recognized international metric developed by physicist Jorge E. Hirsch in 2005 to evaluate scientists' performance and productivity. The h-index serves as a valuable indicator of the quality and impact of an author's contributions to this field (Abafe et al., 2021). In terms of h-index rankings, Weary M. Daniel leads the list with an h-index of 20, followed by Emily K. Miler-Cushon (h-19) and Donagh P. Berry (h-18), as shown in Figure 3(b).

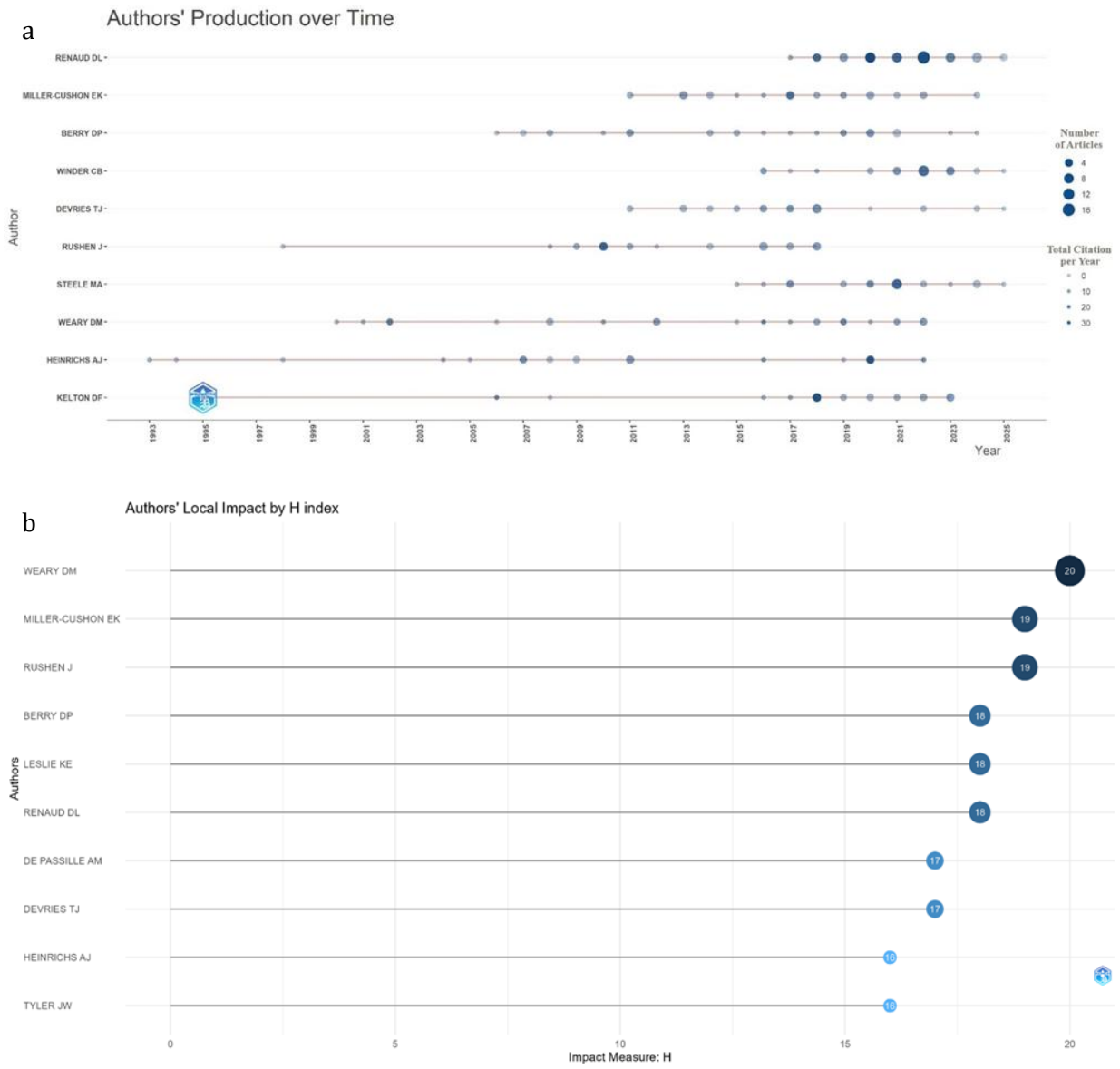


Figure 3. Authors' production over time (a) and authors' local impact by H index (b) years.

3.3. Countries and Network Analysis for Co-Authorship

The distribution of countries of authors involved in research on major factors affecting calf losses can be observed in Figure 4(a). This bar graph categorizes the number of documents contributed by authors from various countries into "Single Country Publications (SCP)" and "Multiple Country Publications (MCP)". As illustrated in the figure, the USA stands out with the highest number of publications and maintaining a leading position. Canada and Ireland follow, demonstrating a strong presence in research activities within these countries. The United Kingdom, Germany, and Australia also attract attention with significant publication numbers.

The graph underscores the extent of international collaboration in this field. The distinction between SCP and MCP for each country highlights the collaborative

efforts among researchers. For instance, while some countries exhibit a high number of single-country publications, countries like the USA display a notable balance between single and multiple country collaborations, indicating a robust network of international research partnerships. Turkey, on the other hand, ranks 13th among these countries. Although Turkey has fewer publications compared to other countries, it remains among the contributing nations in this field. Depending on the type of collaboration, authors from Turkey are involved in both single-country and multi-country publications. Analyzing the global landscape of research on the major factors affecting calf losses given in Figure 4(c), a strong collaboration can be seen in North America, particularly between the United States and Canada, as well as across the world, including Europe and Oceania.

Figure 4(d) presents a network analysis graph illustrating the co-authorship connections among authors in research on major factors affecting calf losses. Each node represents a different author, while the size of the node indicates the level of contribution or influence based on the author's publications. The connections (lines) between the nodes demonstrate collaboration, indicating which authors have co-published works together. Weaver DM, who published in 2000, appears as a central figure in this network, suggesting significant contributions to the field and indicating that they are likely engaged in numerous collaborations.

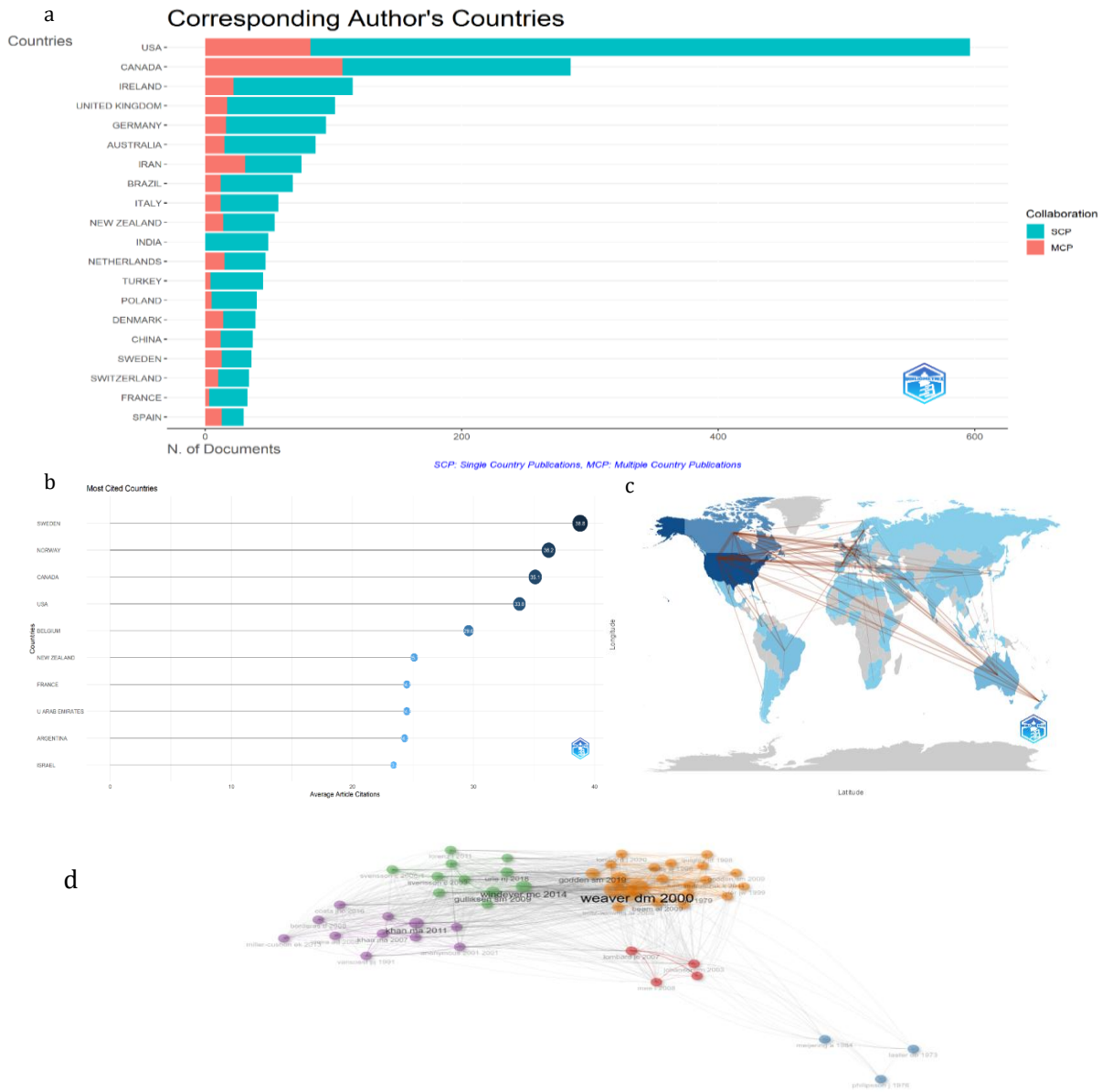


Figure 4. Network analysis for co-authorship and countries (a) Countries of leading corresponding authors; (b) Global trends of the most cited countries; (c) Global network of collaborations among authors; (d) Co-occurrence network visualization map of authors.

3.4. Most Influential Journals

Based on Bradford's Law of Scattering, the connection between published articles and journals has been examined. According to this law, a topic can only be published in a limited number of sources, which form the nucleus of the journal's articles. It emphasizes that these journals will represent a significant percentage (one-third) of the published articles, followed by a broader second group of journals that accounts for another third, and a much wider group that encompasses the remaining third (Abafe et al., 2021). As a result, three clusters comprising a total of 251 journals were analyzed according to the cumulative frequency of citations and publications: the most prominent cluster consists of 2 journals (Journal of Dairy Science and Journal of Animal Science) covering 783 articles. The second cluster includes 26 journals encompassing 806 articles, while the third cluster contains 223 sources that publish 770 articles. In this context, the five most productive journals are shown in Figure 5.

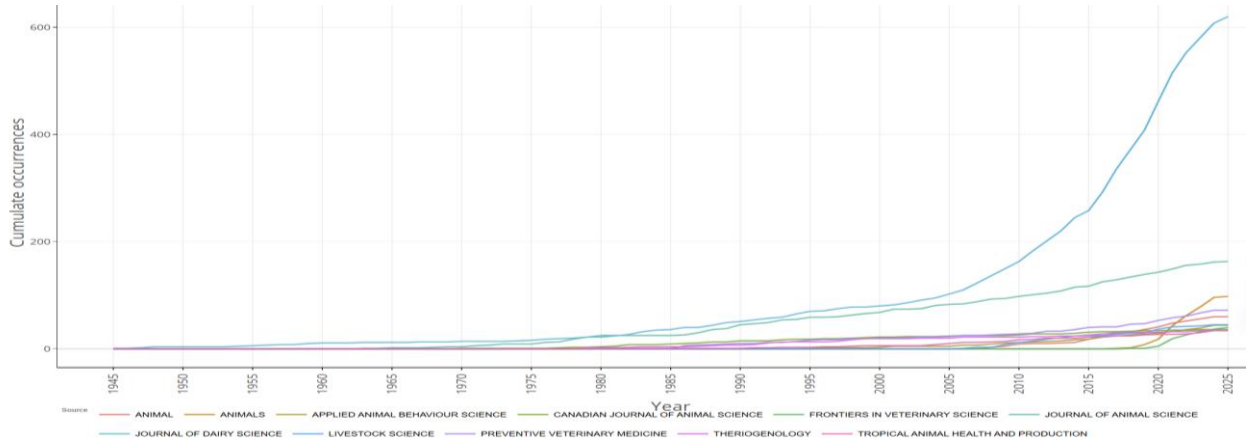


Figure 5. The most 10 productive journals on research regarding major influences on calf mortalities from 1945 to 2025.

Figures 6(a-c) presents the top 10 journals based on citations, impact, and number of publications according to the H, TC, and G-indexes. In all three areas, the Journal of Dairy Science, Journal of Animal Science, and Preventive Veterinary Science share the top three positions. Regarding the major influences on calf losses, the journals with the highest number of publications are listed as follows in Figure 6(d): Journal of Dairy Science (620), Journal of Animal Science (163), and Animals (98).

Figure 6. Source Analysis (a) Source local impact by H-index; (b) Source local impact by total citations (TC) index; (c) Source local impact by G-index; (d) Most local cited sources.

3.5. Distribution of Most Productive Affiliations

The distribution of articles produced by various academic institutions on major factors affecting calf losses is illustrated in Figure 7, showing that the University of Guelph has the highest number of articles (358), followed by other institutions such as the

University of Florida (132) and the University of British Columbia (111).

3.6. Collaboration Network of Keywords and Their Evolution Over Time

In calf mortality researches, the relationships among terms, including titles, keywords, and abstracts, are given in Figure 8(a). As emphasized in the figure, specific keywords such as "calving", "mortality", and "performance" are connected to broader concepts in the field, such as "cattle", "health", and "feeding" terms. The lines linking these terms indicate their relevance and frequency of occurrence in the literature. The thematic connections among key concepts about calf mortality can be used to identify focal points and areas that warrant further investigation. Clusters of keywords such as 'performance', 'health', and 'risk factors' in Figure 8(b) not only highlight important thematic areas in the field but also provide insight into common trends and potential gaps in existing literature.

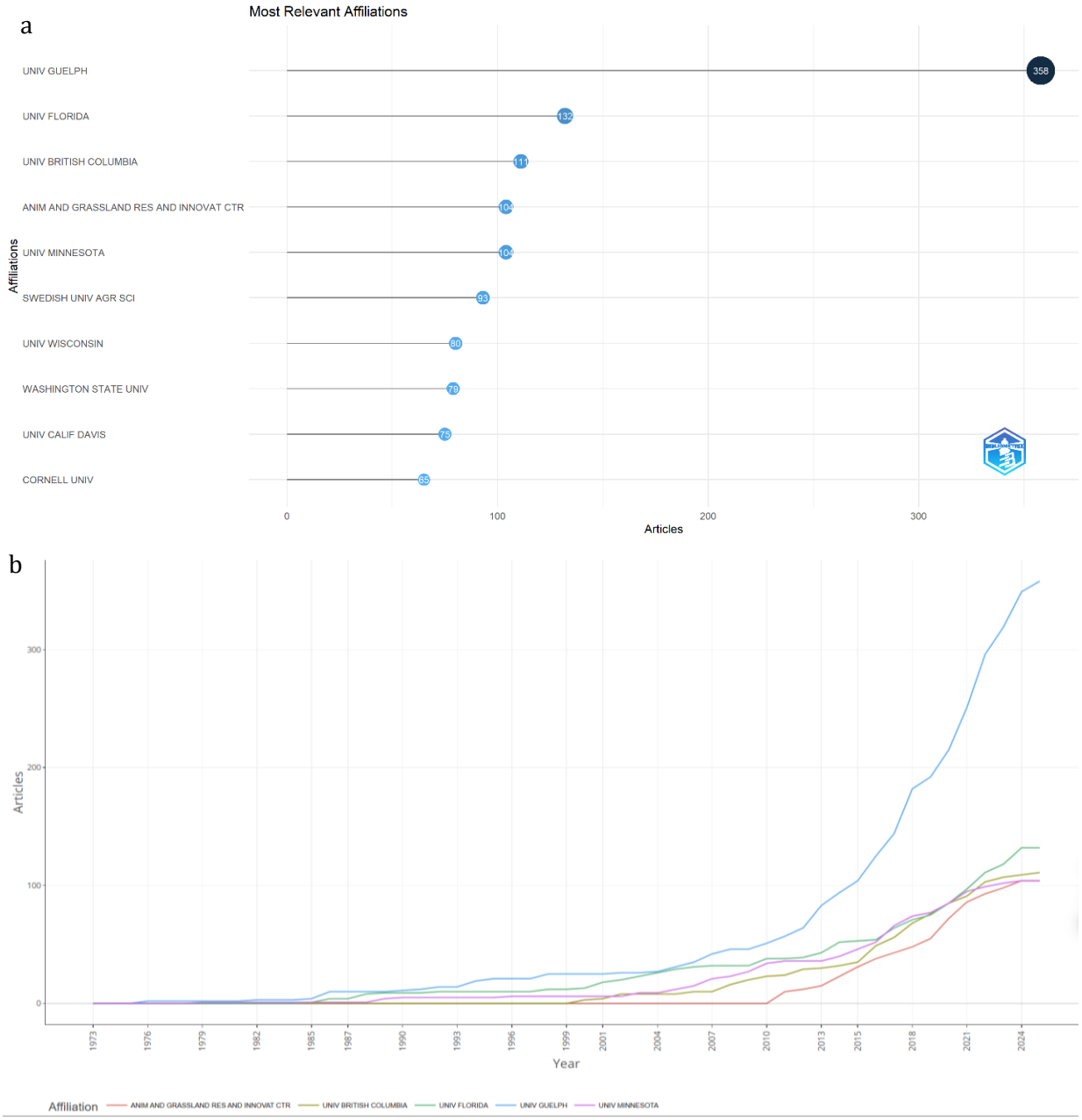
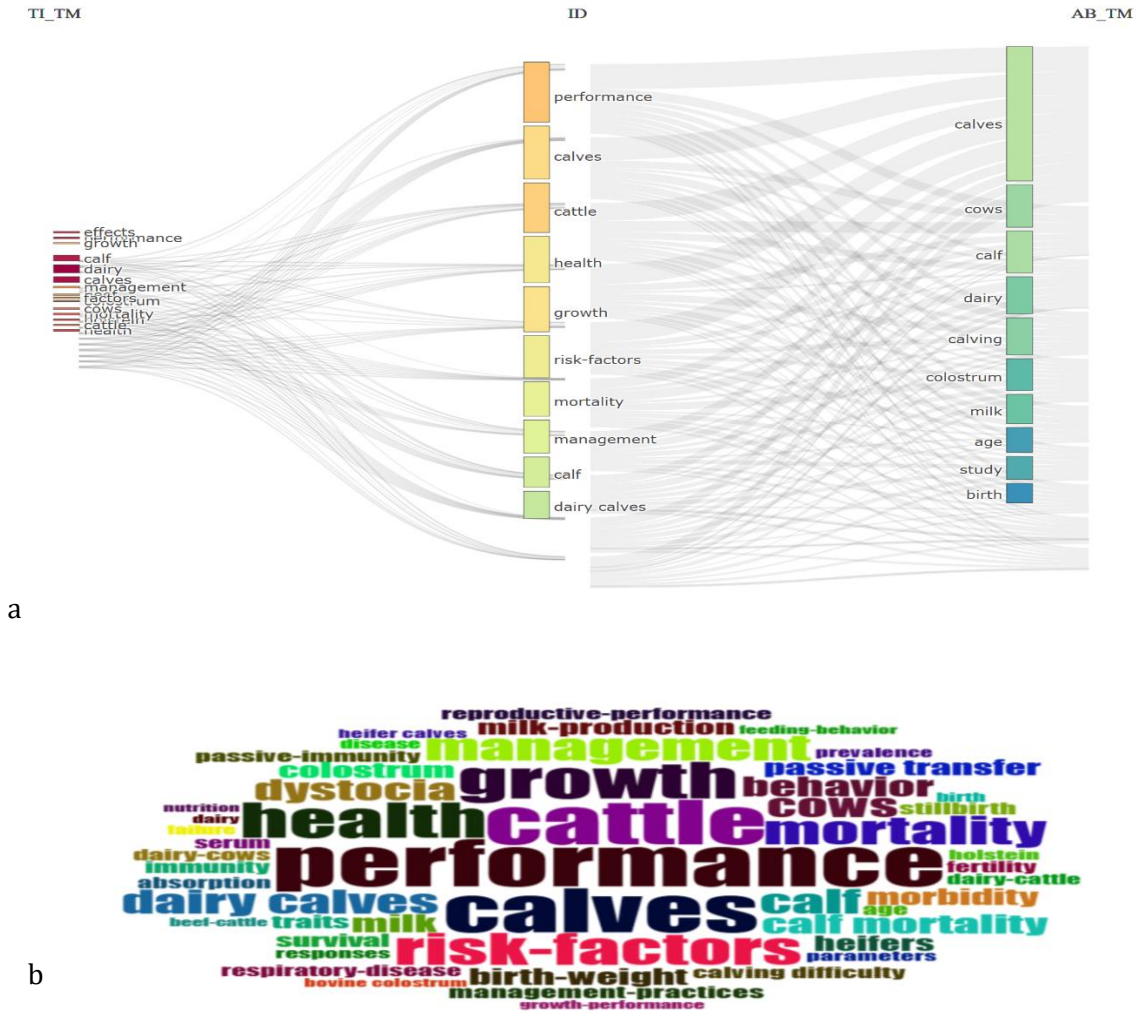


Figure 7. Number of articles produced by various academic institutions on major influencing factors on calf mortalities.



a

b

Figure 8. (a) Analysis and Co-occurrence Network of Keywords, (b) Keywords plus cloud.

3.7. Strategic Diagram

The strategic diagram analysis indicates the thematic evolution of calf research across four distinct quadrants (Figure 9). The terms 'milk', 'feed requirements', and 'growth performance', highlighted in the major theme, represent well-developed and highly central issues that drive the field forward. The lower right quadrant contains core themes like 'cattle', 'calf mortality', and 'health', which form the foundational knowledge base of this research area. Niche themes such as 'rumen development', 'bovine colostrum', and 'immunoglobulin concentration' emerge as specialized yet well-developed topics with significant potential for future integration into mainstream research. The emerging themes indicate areas that are gaining relevance and have the potential to evolve into more centralized research topics. This thematic breakdown clearly illustrates a mature research field characterized by established foundations, active main topics, and emerging specialized areas, all of which contribute to a comprehensive understanding of calf health and management.

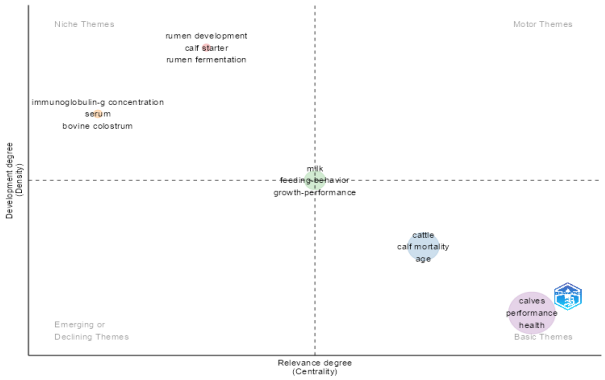


Figure 9. Strategic diagram of research themes related to calf mortality.

3.8. Conceptual Structure Analysis

Figure 10 presents the conceptual structure map generated using MCA (Multiple Correspondence Analysis), illustrating the intellectual structure of the calf research literature. At the core of the map, central concepts such as calves, heifers and dairy demonstrate their fundamental roles in connecting various research domains. The map identifies four distinct thematic clusters: a feeding-behavior cluster in the upper region encompassing nutrition, growth performance, and milk-

related topics; a health cluster on the right side focusing on passive immunity, colostrum, and respiratory diseases; a reproduction cluster on the left containing fertility, dystocia, and birth weight; and a management cluster in the center addressing management practices and risk factors. The spatial arrangement shows that topics located near each other, like mortality and risk factors, are often studied together in literature. This visualization effectively illustrates how reproduction and fertility keywords are conceptually separated from health and disease keywords, while feeding and growth research is distinguished from general management issues (bottom), providing researchers with a comprehensive overview of the field's intellectual structure and potential research gaps.

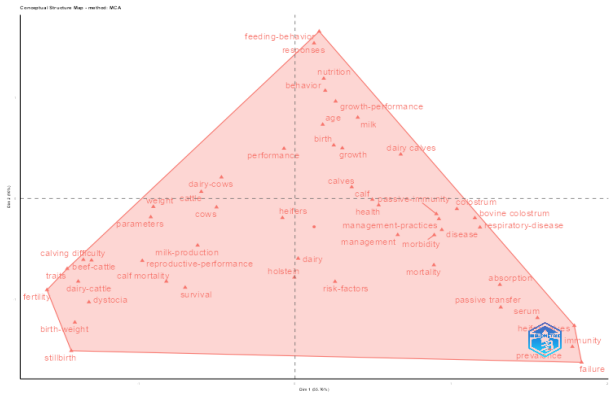


Figure 10. Conceptual structure analysis of major factors affecting calf losses.

4. Discussion

Bibliometric reviews are valuable tools for understanding the global development of research. This study demonstrates that the primary items influencing calf mortality can be categorized into three main factors. The first one is farm management, which encompasses passive immunity, immunoglobulin concentrations, and colostrum intake. These studies underscore the significance of the immune system in newborn calves and highlight how failures in passive immunity can impact mortality rates. The most cited work in this field (LeBlanc et al., 2006) focused on neonatal calf health, deriving insights from a 25-year evaluation of studies conducted in the United States and Canada, and examined new best management practices and strategies for passive immunity transfer. Recent studies have shown an increase in research related to calf management (Carullo et al., 2023), particularly noting a surge in studies on calf mortality since 2018. That same year was declared the "Year of the Calf" in Turkey to prevent calf mortalities and raise awareness. Moreover, effective calf management can significantly reduce, if not completely prevent, potential issues when it is well understood and simple precautions are taken. Weaver et al. (2000) observed that the transfer of IgG from the intestinal epithelium is most efficient during the first four hours of life and declines within 12 hours. The study also contributed to the field of calf rearing by emphasizing the importance of timely provision of adequate and quality colostrum feeding to ensure passive immunity, as well as addressing the separation of calves from their dams at birth to improve calf health. Fischer et al. (2018) demonstrated that calves receiving colostrum immediately after birth have higher serum IgG levels compared to those fed later. Additionally, the study by Sedó et al. (2024) revealed that calves receiving colostrum within the first hour of life face a lower risk of perinatal mortality than those fed colostrum later. Numerous studies have also shown that providing milk in amounts exceeding 10% of body weight promotes weight gains in calf feeding (Diaz et al., 2001; Cowles et al., 2006; Rosenberger et al., 2016).

The second factor, affecting calf mortality, is a factor centered on nutrition and growth performance. It clarifies the interrelationships among genetic and reproductive factors such as birth weight, calving difficulties, fertility, and milk production, while also illustrating their close connection to calf mortality rates. Additionally, it has been suggested that factors like birth weight and calving difficulties may impact production and reproduction in the later stages of calves' lives (Soberon and Van Amburgh, 2013; Dance et al., 2015). Although primiparous cows had lower milk yield during the first 60 days of lactation after giving birth to heavier calves, no relationship was observed between calf birth weight and total milk production over the 305-days lactation period. Consequently, it has been reported that the influence of birth weight on milk yield is only apparent in the early stages of lactation and diminishes throughout the entire lactation period. In contrast, multiparous cows that gave birth to heavier calves exhibited higher milk production, likely due to their more complete development and established hierarchy within the herd, which makes them less susceptible to postpartum stress compared to primiparous cows, as highlighted by Condon et al. (2024).

Berry et al. (2007) reported that in their studies on Holstein-Friesian cows, experiences of dystocia or stillbirth negatively affect milk production, somatic cell scores (SCS), and reproductive performance. Similarly, dystocia significantly increased the risk of stillbirths in heifer calves and in calves born to multiparous dams compared to bull calves and those born to primiparous dams. Moreover, both the stillbirth rates and calf mortality rates within the first 30 days postpartum were also increased (Lombard et al., 2007). Jenkins et al. (2016) highlighted the need for a more cautious approach in breeding strategies due to the increased incidence of perinatal mortality in calves associated with both shorter and longer gestation lengths. Nonetheless, a common consensus among these studies underscores the necessity for further research to better understand the later developmental stages of calves.

The last factor, which affects calf mortality, involves management factors related to calf rearing, animal

welfare, behavior, and performance. These factors demonstrate that effective management practices directly influence calf health and mortality rates. Notably, leading authors in this field, such as Daniel M. Weary, Emily K. Miler-Cushon, and Jeffrey Rushen, have concentrated on animal behavior and calf rearing. Weary has emphasized the increase in behavioral studies on calves, noting in his research that prolonged suckling by the cow does not diminish milk yield; in fact, this practice has a positive effect on calf development. Furthermore, he has indicated that very early separation of calves from their dams can mitigate the acute response to stress in both cows and calves.

As highlighted in the studies, the management, care, and nutrition of calves, which represent the future of the herd, are critically important. In recent years, there has been an urgent need for research focused on calf mortality and the elimination of contributing factors, as well as for establishing successful calf rearing programs.

The management and welfare of calves are essential for the sustainability and productivity of dairy herds. By implementing effective management practices, understanding the genetic and nutritional factors that influence calf health, and addressing welfare concerns, significant improvements can be made in calf survival rates and overall herd performance. Therefore, an integrated approach that incorporates immunological, nutritional, and management elements is vital for advancing research and best practices in calf rearing.

5. Conclusion

Although high calf mortality rates directly cause losses for farms and the cattle population, they are often overlooked and not given sufficient importance. However, these losses can be easily prevented through effective methods. Recognizing and prioritizing this issue is crucial, and proactive steps should be taken, especially on problematic farms, at the national level, and across all relevant organizations. Data recording, research, breeding programs, veterinary services, extension activities, and farmer organizations all have vital roles in addressing this problem. As studies have shown, calf mortality rates range from 2% to 20%, indicating that this is a significant issue that cannot be underestimated. Therefore, in this study, a bibliometric analysis of scientific literature on calf mortality was conducted to provide a detailed evaluation. This approach aims to reveal the current state of research, identify trends, and highlight gaps in the existing literature to facilitate progress and improvements in the field.

Author Contributions

Percentages of the authors' contributions are present below. All authors reviewed and approved final version of the manuscript.

	A.Ö.Ş.	R.A.D.	Y.A.	A.K.C.T.
C	25	25	25	25
D	25	25	25	25
S	25	25	25	25
DCP	25	25	25	25
DAI	25	25	25	25
L	25	25	25	25
W	25	25	25	25
CR	25	25	25	25
SR	25	25	25	25

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Since no studies involving humans or animals were conducted, ethical committee approval was not required for this study.

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