

Colostrum-microbiota interaction and its relationship with neonatal health and pubertal development: Bibliometric analysis (2010-2025)

Interacción calostro-microbiota y su relación con la salud neonatal y el desarrollo puberal: Análisis bibliométrico (2010-2025)

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ABSTRACT. In modern dairy production systems, calf survival and productive performance largely depend on physiological events occurring during the first hours of life. In this context, the colostrum-microbiota interaction has gained relevance due to its influence on passive immunity transfer, neonatal health, and early development. Accordingly, the objective of this study was to analyze research trends related to colostrum-microbiota interaction in dairy calves and its relationship with neonatal health and pubertal development from 2010 to 2025. A bibliometric analysis was conducted using data retrieved from Google Scholar, Scopus, and ScienceDirect, applying Boolean operators associated with colostrum quality, passive immunity, microbiota, and pubertal development. Records were exported in RIS format, duplicates were removed, and the data were analyzed using VOSviewer (version 1.6.20) and Microsoft Excel to evaluate publication trends, scientific collaboration networks, keyword co-occurrence, and the most cited articles. A total of 225 publications were identified, mainly research articles. Scientific production increased notably from 2018 onward, reaching its peak in 2025. Co-occurrence maps revealed clusters associated with passive immunity, microbiota, digestive health, and productive performance, with the highest output in China, the United States, and Switzerland. These results indicate sustained growth in scientific interest; however, knowledge gaps remain regarding its relationship with early reproductive development, representing an opportunity for future research in dairy production systems.

Keywords: Bibliometrics, early programming, immunity transfer, reproductive performance, VOSviewer.

RESUMEN. En los sistemas lecheros modernos, la supervivencia y el desempeño productivo de las becerras dependen en gran medida de los eventos fisiológicos que ocurren durante las primeras horas de vida. En este contexto, la interacción calostro-microbiota ha cobrado relevancia por su influencia en la transferencia de inmunidad pasiva, la salud neonatal y el desarrollo temprano. Bajo este enfoque, el objetivo del presente estudio fue analizar las tendencias de investigación relacionadas con la interacción calostro-microbiota en becerras lecheras y su relación con la salud neonatal y el desarrollo puberal durante el periodo 2010-2025. Se realizó un análisis bibliométrico mediante la recuperación de información en Google Scholar, Scopus y ScienceDirect, utilizando operadores booleanos asociados con calidad de calostro, inmunidad pasiva, microbiota y desarrollo puberal. Los registros fueron exportados en formato RIS, depurados para eliminar duplicados y analizados mediante VOSviewer (versión 1.6.20) y Microsoft Excel, con el fin de evaluar tendencias de publicación, redes de colaboración científica, coocurrencia de palabras clave y artículos más citados. Se identificaron 225 publicaciones, principalmente artículos de investigación. La producción científica mostró un incremento notable a partir de 2018, alcanzando su máximo en 2025. Los mapas de coocurrencia revelaron clústeres asociados con inmunidad pasiva, microbiota, salud digestiva y desempeño productivo, con mayor producción en China, Estados Unidos y Suiza. Estos resultados evidencian un crecimiento sostenido del interés científico; sin embargo, persisten vacíos sobre su relación con el desarrollo reproductivo temprano, lo que representa una oportunidad para futuras investigaciones en sistemas de producción lechera.

Palabras clave: Bibliometría, programación temprana, transferencia de inmunidad, desempeño reproductivo, VOSviewer.

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INTRODUCTION

The dairy industry has consolidated itself as a strategic activity within contemporary agri-food systems, not only because of its nutritional contribution but also because of the significant economic spillover it generates (FAO 2022, Priyashantha 2025). In this regard, the Comarca Lagunera, an agroecological region located in northern Mexico, stands out as one of the main clusters of bovine milk production at the continental level, concentrating more than 500 000 Holstein cows in intensive, technified, and modern production systems that generate more than 3,000 million liters of milk annually, with an estimated value of 1.42 billion dollars, in close linkage with a dairy industrialization structure with national and international projection (Navarrete-Molina *et al.* 2019, Rodríguez-Sánchez *et al.* 2024).

A successful artificial rearing system is fundamental for the economic and productive sustainability of the dairy cattle industry (Ram *et al.* 2020). Because it is based on the early separation of the calf from the dam, colostrum quality becomes a key factor, as it determines the transfer of immunity and long-term productive viability (Lombard *et al.* 2020). Colostrum is the first postpartum secretion and is characterized by a high concentration of immunoglobulins, mainly IgG1, as well as lactoferrin, lysozyme, leukocytes, fat-soluble vitamins, minerals, and growth factors (IGF-I and IGF-II), whose ingestion during the first hours of life is essential to establish passive immunity, reduce the incidence of neonatal diseases, and promote growth (Godden *et al.* 2019, Lopez and Heinrichs 2022). Consequently, the early and adequate intake of high-quality colostrum has been identified as an indispensable condition for the health and survival of newborn calves (McGuirk and Collins 2004). In addition to passive immunity, colostrum is also closely linked to the initial colonization of the gastrointestinal tract, giving rise to the gastrointestinal microbiota (Malmuthuge *et al.* 2015, Puppel *et al.* 2020), which is fundamental in the ontogenesis of the immune system since it stimulates lymphocyte differentiation, the expansion of cellular antigens, and the establishment of signaling pathways that integrate immune responses with intestinal homeostasis and host growth (Amin and Seifert 2021). During the early postnatal stage, a balanced microbiota plays a central role in the regulation of the reproductive endocrine axis by modulating key hormones such as leptin, IGF-1, estrogen, and progesterone, which are essential for sexual maturation (Fantuz *et al.* 2024, Khan *et al.* 2024). Therefore, the colostrum-microbiota interaction is not limited only to neonatal survival but extends to critical stages of development, influencing the age at first calving and the reproductive-productive efficiency of dairy herds (Quereda *et al.* 2020, Ault-Seay *et al.* 2022).

Based on the above, it is essential to organize and systematize the available information addressing these processes in order to obtain an integral understanding of their temporal dynamics. From this perspective, understanding the state of the art in a specific field is essential to recognize gaps in the scientific literature, identify emerging dynamics, and support research projects with greater relevance; this approach defines chronological trajectories and interrelationships that facilitate the formulation of hypotheses and more robust research lines (Oliveira *et al.* 2024). Undoubtedly, bibliometric analyses, conceived as the quantitative analysis of scientific production and its metadata (e.g., keywords, citations, abstracts), constitute a key tool, as they allow the identification of research patterns, emerging dynamics, and collaboration networks (Michán and Muñoz-Velasco

2013, Passas 2024, Manterola *et al.* 2024). The objective of the present study was to analyze the scientific production published in bibliographic databases regarding the colostrum-microbiota interaction in dairy calves and its impact on neonatal health, growth, and pubertal maturation during 2010-2025.

MATERIALS AND METHODS

Information retrieval and search strategy

A systematic search was conducted in the Scopus, ScienceDirect, and Google Scholar databases, focusing on studies involving dairy calves that addressed colostrum quality, intestinal microbiota modulation, neonatal health, growth, and pubertal development. The search included original research articles, review papers, book chapters, and books published between 2010 and 2025. Boolean operators were applied to structure the search strategy using the following expression: ("colostrum quality" OR "passive immunity" OR "IgG") AND ("gut microbiota" OR "intestinal microbiota") AND ("puberty onset" OR "dairy calves").

Inclusion and exclusion criteria

Selection criteria were subsequently applied to refine the retrieved records. Only publications written in English and directly related to the research topic within the fields of animal production or veterinary medicine, and containing the keywords defined in the search strategy, were included (Kumar *et al.* 2024).

Data migration and cleaning

The retrieved records were exported in .RIS format (Research Information Systems Incorporated) and integrated into a single database. During the data cleaning process, duplicate records were removed, inconsistencies were corrected, and the information was standardized to ensure the coherence and reliability of the analysis.

Bibliometric analysis

The curated database was analyzed using VOSviewer version 1.6.20 (Leiden University, The Netherlands), specialized software for the construction and visualization of bibliometric networks. Keyword co-occurrence, co-authorship, and reference co-citation maps were generated to identify thematic clusters, collaboration patterns, and the intellectual structure of the research field. Descriptive analyses were complemented using Microsoft Excel, which was employed for data organization and the visualization of publication frequency and temporal trends.

Visualization and interpretation

Network maps and descriptive graphs were generated to identify thematic clusters, levels of collaboration, and temporal trends in scientific production (Van-Eck and Waltman 2010). The resulting visualizations served as the basis for interpretation, while the contextualization of global research trends provided an integrated perspective on the patterns identified in the bibliometric analysis (Lim and Kumar 2024).

RESULTS

During the analyzed period (2010-2025), a total of 225 publications related to the research topic (colostrum, microbiota, neonatal health, and pubertal development in dairy calves) were identified (Figure 1). These documents were retrieved from three scientific databases: Google Scholar (n = 126), ScienceDirect (n = 68), and Scopus (n = 31). Most publications corresponded to original research articles (n = 161), followed by review articles (n = 58) and book chapters (n = 6), indicating that the majority of the scientific output in this field is based on primary research, while a smaller proportion corresponds to knowledge synthesis studies.

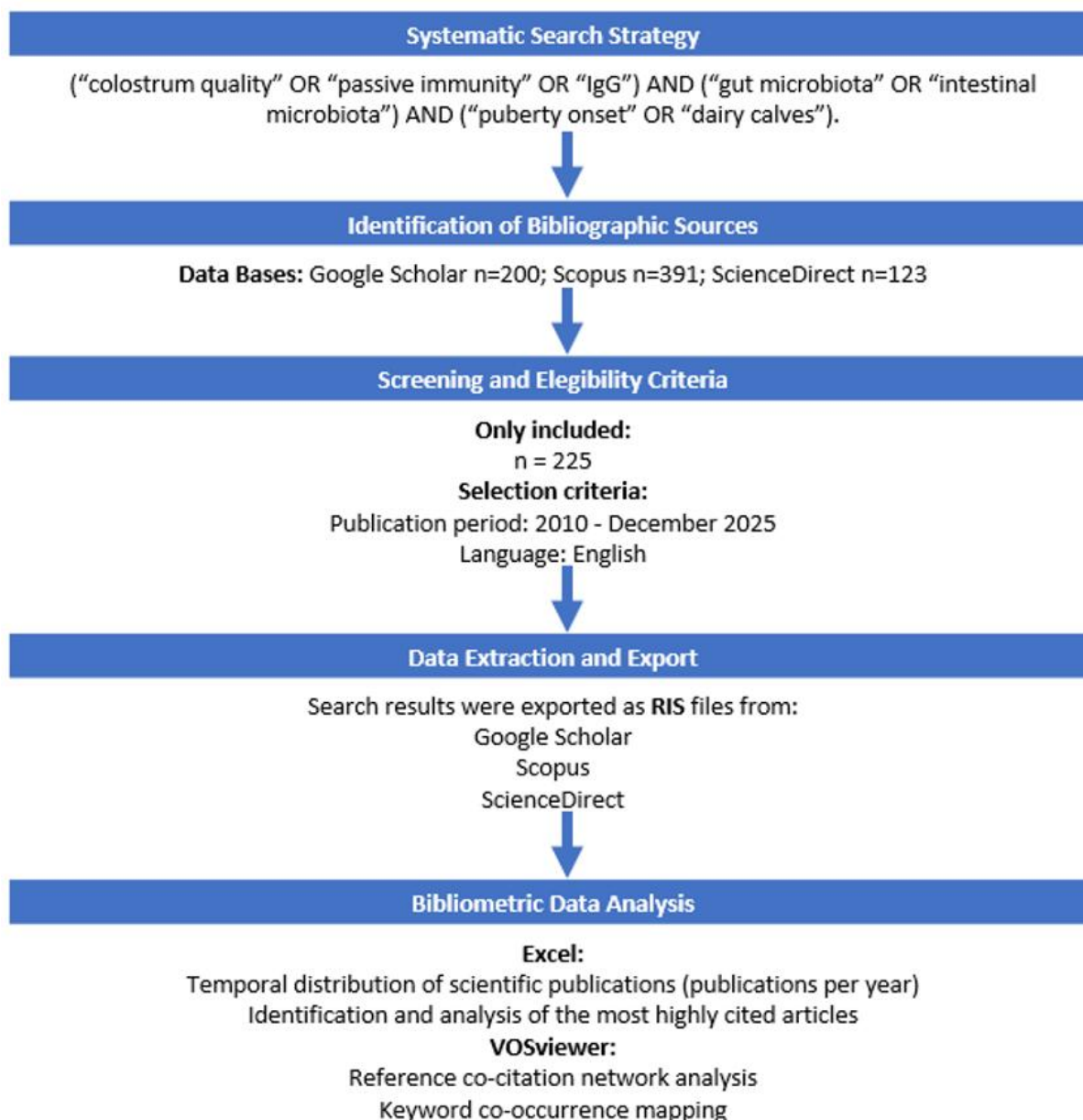


Figure 1. Workflow of literature identification and data collection.

At the beginning of the analyzed period, a low number of publications was observed during the early years, particularly between 2010 and 2014, when the number of documents was four or fewer publications per year (Figure 2). This pattern reflects the still emerging nature of this research area during that stage. However, as the period progressed, a gradual increase in scientific production was observed, indicating the progressive consolidation of the research field.

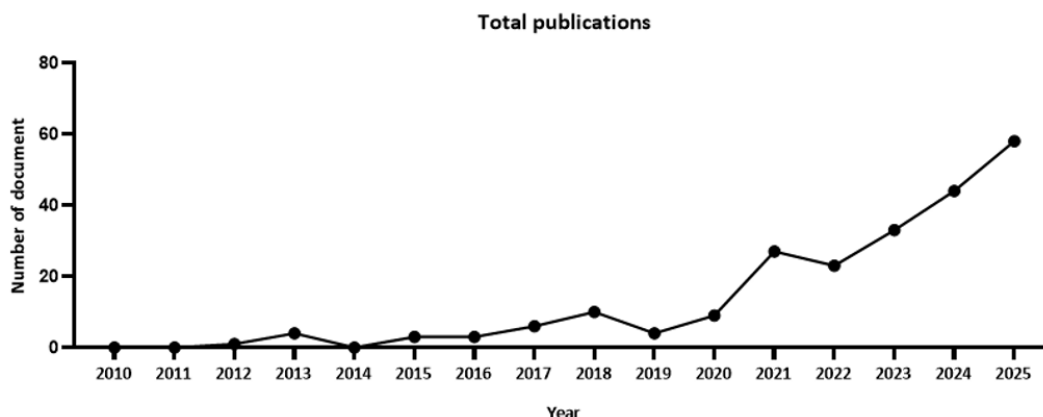


Figure 2. Annual scientific production during 2010-2025.

Analysis of the entire series showed a mean annual production of 14.1 ± 17.0 publications, reflecting an irregular pattern during the initial phase and a notable increase in more recent years. Starting in 2018, a sustained growth in the number of publications was observed, reaching its peak in 2025 with 58 documents. Furthermore, the period 2020-2025 accounted for approximately 86% (194 publications) of the total analyzed documents, suggesting a recent and growing scientific interest in the study of the interaction between colostrum, early microbial colonization, and its implications for the health and physiological development of dairy calves.

The most cited publications in the research field (colostrum, microbiota, neonatal health, and pubertal development in dairy calves) are summarized in Table 1. For this analysis, only the Scopus database was used because it provides a standardized citation index for each document, allowing a consistent assessment of citation impact. The citation cut-off date considered in this study was March 1, 2026. Among the retrieved publications, the article entitled Early supplementation of *Saccharomyces cerevisiae boulardii* CNCM I-1079 in newborn dairy calves increases IgA production in the intestine at 1 week of age, published in the Journal of Dairy Science, recorded the highest citation impact, with a total of 39 citations.

The distribution of scientific journals publishing studies on the journals publishing research in this field are presented in Table 2, together with their bibliometric indicators, including quartile ranking, subject category, impact factor (IF), and country of publication, according to the information available up to March 2026.

A total of 94 journals were identified. Among them, Journal of Dairy Science leads the list with 31 documents, classified as Q1 within the Agricultural and Biological Sciences category and with an impact factor of 4.4, published in the United States. This journal is followed by Animals with 25 documents and Frontiers in Veterinary Science with 17 documents, both also classified in the first

quartile (Q1). Additionally, 59 journals published only one document, representing approximately 62.8% of the total identified sources, which indicates a high dispersion of scientific production in this field, distributed across a wide variety of specialized journals in animal science, microbiology, and veterinary medicine.

Table 1. Most cited articles related to the research topic (colostrum, microbiota, neonatal health, and pubertal development in dairy calves) according to the Scopus database (cut-off date: March 1, 2026).

Rank	Title	Citations	Authors	Journal	Year	Type
1	Early supplementation of <i>Saccharomyces cerevisiae</i> boulardii CNCM I-1079 in newborn dairy calves increases IgA production in the intestine at 1 week of age	39	Villot <i>et al.</i>	Journal of Dairy Science	2020	Article
2	Analysis of the developing gut microbiota in young dairy calves-impact of colostrum microbiota and gut disturbances	36	Hang <i>et al.</i>	Tropical Animal Health and Production	2021	Article
3	Combined supplementation of sodium humate and glutamine reduced diarrhea incidence of weaned calves by intestinal microbiota and metabolites changes	13	Wang <i>et al.</i>	Journal of Animal Science	2021	Article
4	The role of anti- <i>E. coli</i> antibody from maternal colostrum on the colonization of newborn dairy calves gut with <i>Escherichia coli</i> and the development of clinical diarrhea	10	Gomes <i>et al.</i>	Animal - Open Space	2023	Article
5	Early-life <i>Clostridium butyricum</i> supplementation improved rumen development and immune by promoting the maturation of intestinal microbiota	3	Zhu <i>et al.</i>	Journal of Agriculture and Food Research	2024	Article

Table 2. Journals with the highest scientific production on the study topic (colostrum, microbiota, neonatal health, and pubertal development in dairy calves)

Journals	Documents	Quartile	Category	IF	Country
Journal of Dairy Science	31	Q1	Agricultural and Biological Sciences	4.4	United States
Animals	25	Q1	Agricultural and Biological Sciences	2.7	Switzerland
Frontiers in Veterinary Science	17	Q1	Veterinary	2.9	Switzerland
Animal Feed Science and Technology	8	Q1	Agricultural and Biological Sciences	2.7	Netherlands
Chinese Journal of Animal Nutrition	8	Q4	Agricultural and Biological Sciences	0.8	China

The distribution of publications according to the country of origin of the journals reveals the geographical concentration of research outputs related to the research field. As shown in Table 3, China ranks first with 48 publications, followed by the United States with 40 and Switzerland with 36. In subsequent positions are the United Kingdom and the Netherlands, both with 17 publications.

Overall, these countries account for the majority of the journals in which studies on this topic are published, reflecting the concentration of editorial and scientific infrastructure in regions with high research activity in animal science, microbiology, and veterinary medicine.

The authors with the greatest contribution to the scientific production were identified based on the number of documents included in the bibliographic corpus and the Total Link Strength (TLS), an indicator that represents the intensity of collaboration relationships among authors within the analyzed scientific network. This metric allows the assessment of the degree of interaction among

researchers working on topics related to the interaction between colostrum, microbiota, early health, and pubertal development in dairy calves (Table 4).

Table 3. Geographic distribution of journals publishing research on the colostrum-microbiota interaction in dairy calves.

Rank	Number	Number of publications
1	China	48
2	United States	40
3	Switzerland	36
4	United Kingdom	17
5	Netherlands	17

Table 4. Top 5 authors with the highest scientific contribution in the research topic of colostrum, microbiota, neonatal health, and pubertal development in dairy calves.

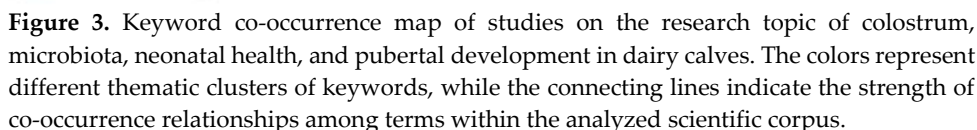
Rank	Author	Articles	TLS	Citations	H-index	Affiliation	Country
1	Li, Shengli	289	12	4399	36	China Agricultural University	China
2	Guan, Le Luo	311	11	11245	69	University of British Columbia	Canada
3	Li, Yuanyuan	14	9	59	4	Shihezi University	China
4	Cao, Zhijun	199	8	3824	37	China Agricultural University	China
5	Liu, Yongbin	56	8	440	13	Inner Mongolia Agricultural University	China

Additionally, the academic impact of the authors was evaluated through the number of citations received and the H-index, according to the records available in the Scopus database. These indicators make it possible to identify the researchers with the greatest scientific influence within this research field.

The keyword co-occurrence map (Figure 3) allowed the identification of the main concepts that structure the research field. Based on the bibliometric analysis, a thematic network was generated in which the terms are grouped into different clusters that reflect the main research lines within the study area.

The first cluster is dominated by terms such as “bovine,” “colostrum,” “animals, newborn,” and “pregnancy,” representing the central research axis focused on neonatal physiology, passive immunity transfer, and colostrum management in dairy cattle. This group includes the most general concepts of the field and functions as the structural core of the scientific network. The second cluster includes keywords such as “diarrhea,” “calf (bovine),” “intestinal flora,” and “immunoglobulin M,” mainly associated with studies related to digestive health, enteric diseases, and immune development in calves during the early stages of life.

The third cluster groups terms such as “microbiota,” “16S rRNA,” “lactobacillus,” and “microbial diversity,” reflecting a research line focused on the molecular characterization of microbiota through metagenomic tools applied to the study of the bovine microbiome. The fourth cluster incorporates keywords such as “diet,” “veterinary medicine,” “growth performance,” and “weaning,” indicating a thematic line related to animal nutrition, feeding management, and the productive performance of calves during the rearing period.



Among the main collaboration groups, networks of researchers led by authors such as Li, S., Wang, X., Cao, Z., and Zhang, Y. were identified. These authors display multiple connections with other researchers within the network, indicating a significant role in the generation of knowledge related to microbiota, health, and pubertal development in dairy calves. The analysis also reveals the presence of several relatively cohesive research cores, particularly associated with Asian institutions, mainly from China. This pattern suggests a leading role in the scientific production related to microbiota, early immunity, and nutrition in dairy calves.

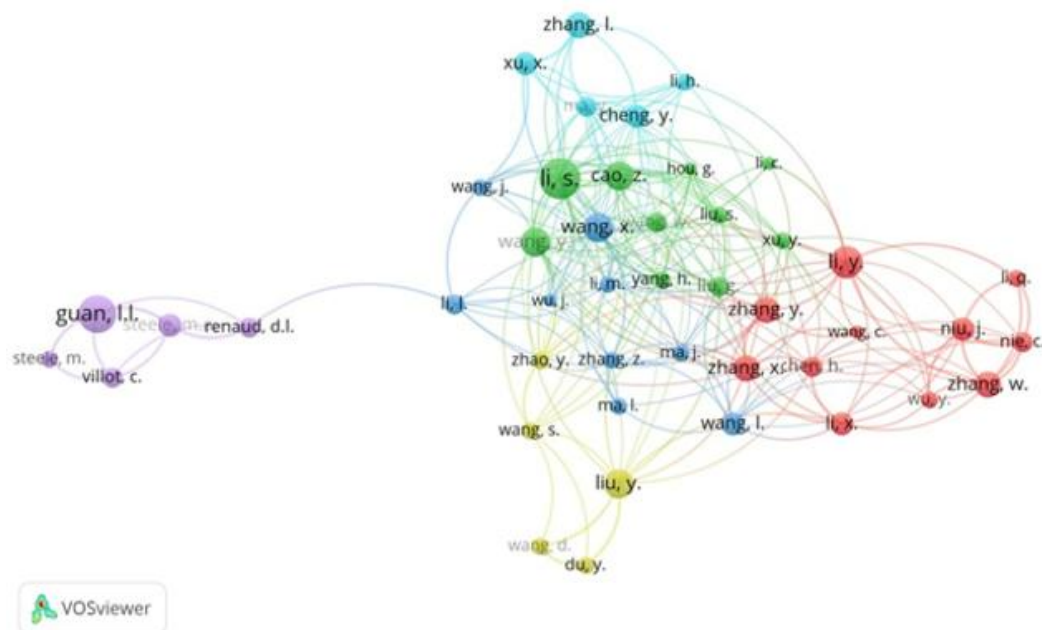


Figure 4. Co-authorship network of authors; colors represent publication year (2010-2025), node size indicates productivity, and links represent collaboration strength.

However, some groups of authors with a lower degree of connectivity or relatively isolated networks were also observed, reflecting a certain level of fragmentation in scientific collaboration within the field. This pattern suggests the existence of multiple research lines developed in parallel, with opportunities to strengthen international cooperation and further integrate scientific collaboration networks in the future.

DISCUSSION

The temporal pattern of scientific production indicates that research on the interaction between colostrum, microbiota, early health, and pubertal development in dairy calves has experienced progressive consolidation over the last decade. Although during the early years of the analyzed period the number of publications was limited, a sustained increase has been observed since 2018, suggesting that this research field has gained increasing relevance within animal sciences and veterinary medicine. In this context, the growth coincides with the expanding interest in understanding the biological processes occurring during the early stages of life in neonatal calves and their influence on the health and productivity of dairy production systems (Meesters *et al.* 2024).

This recent increase is consistent with studies highlighting the importance of colostrum in the early programming of calf health and growth (Silva *et al.* 2024, Duan *et al.* 2024). These authors indicate that colostrum is not only essential for the transfer of passive immunity but also plays a crucial role in the initial modulation of the intestinal microbiota and in the maturation of digestive, metabolic, and reproductive systems, reinforcing its key role in early development and the future productivity of animals. In this sense, the growing number of studies reflects a conceptual shift within dairy

production, where the neonatal period has begun to be recognized as a critical stage for the physiological and productive programming of cattle.

A possible explanation for this increase in scientific output is related to the development of molecular and metagenomic tools that have enabled more precise characterization of the composition and dynamics of the microbiota in domestic animals (Forcina *et al.* 2022, Esener 2025). In particular, techniques based on 16S rRNA gene sequencing and metagenomic analyses have significantly advanced the understanding of the role played by microbial communities in the regulation of the immune system, nutrient metabolism, and disease resistance during the neonatal period (Klein-Jöbstl *et al.* 2019). The interaction between colostrum intake and early microbial colonization has therefore begun to be considered a key factor in the physiological programming of calves, since the intestinal microbiota actively participates in the modulation of immunological, metabolic, and endocrine processes that influence the animal's growth and subsequent development.

The analysis of the journals with the highest scientific output also reflects the consolidation of this research field within specialized journals in animal science and veterinary medicine. In particular, Journal of Dairy Science, Animals, and Frontiers in Veterinary Science account for a substantial proportion of the published studies, demonstrating the interest of these editorial platforms in disseminating research related to neonatal health, nutrition, and the microbiome in dairy cattle. The recurrent presence of these journals also suggests that research on microbiota and early-life programming in cattle is progressively being integrated into the scientific agendas of high-impact journals in animal production.

From a geographical perspective, scientific production is mainly concentrated in countries such as China, where biotechnology has become a key tool to address the growing global demand for food and to improve agricultural productivity through the use of technologies such as genetically modified organisms (GM), gene editing (GE), and other biotechnological approaches aimed at optimizing crops, animals, and microorganisms (Liang *et al.* 2025). Important contributions are also observed from the United States and several European countries. This pattern may be explained by the presence of research centers with well-established scientific infrastructure and specialized programs in animal production, microbiology, and biotechnology applied to livestock systems.

In particular, the leadership observed in Asian institutions may be associated with the recent expansion of research on the animal microbiome and its application in nutritional and management strategies for production animals. Likewise, the concentration of publications in Asian institutions, particularly Chinese ones, supports evidence reported in bibliometric analyses of the Asia-Pacific region, which document an increasing regional leadership in research on animal science and biotechnology applied to livestock systems (Ha 2023). These trends reflect a global expansion of scientific interest in understanding how early-life events, such as early colostrum intake and initial microbial colonization, may influence health, growth, and productive performance throughout the animal's lifetime.

CONCLUSIONS

The bibliometric analysis corresponding to the period 2010-2025 made it possible to identify a sustained growth in scientific production related to the interaction between colostrum, intestinal microbiota, and early health in dairy calves. The results show that research in this field is mainly concentrated on studies addressing passive immunity, intestinal microbiota, and digestive health during the early stages of life. Furthermore, the keyword co-occurrence maps and collaboration networks highlight the multidisciplinary nature of the field, where areas such as animal nutrition, microbiology, immunology, and developmental physiology converge. However, the limited integration between studies on colostrum quality, microbiota modulation, and subsequent reproductive development reveals the existence of a knowledge gap that represents a relevant opportunity for future research.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ADDITIONAL INFORMATION

The datasets used in this research are available from the corresponding author upon reasonable request.

LITERATURE CITED

- Amin N, Seifert J (2021) Dynamic progression of the calf's microbiome and its influence on host health. Computational and Structural Biotechnology Journal 19: 989-1001.
<https://doi.org/10.1016/j.csbj.2021.01.035>
- Ault-Seay TB, Brandt KJ, Henniger MT, Payton RR, Mathew DJ, Moorey SE, Schrick FN, Pohler KG, Smith TPL, Rhinehart JD, Schneider LG, McLean KJ, Myer PR (2022) Bacterial communities of the uterus

- and rumen during heifer development with protein supplementation. *Frontiers in Animal Science* 3: 903909. <https://doi.org/10.3389/fanim.2022.903909>
- Duan H, Sun Q, Chen C, Wang R, Yan W (2024) The effect of bovine colostrum on immunity in people of all ages: A review. *Nutrients* 16: 2007. <https://doi.org/10.3390/nu16132007>
- Esener N (2025) Exploring trends in reproductive system microbiome research in farm animals: A bibliometric approach. *Research in Veterinary Science* 186: 105583. <https://doi.org/10.1016/j.rvsc.2025.105583>
- Fantuz F, Fatica A, Salimei E, Marcantoni F, Todini L (2024) Nutrition, growth, and age at puberty in heifers. *Animals* 14: 2801. <https://doi.org/10.3390/ani14192801>
- FAO (2022) Dairy market review: Emerging trends and outlook 2022. Food and Agriculture Organization of the United Nations. Rome, Italy. <https://www.fao.org/3/cc3418en/cc3418en.pdf>
- Forcina G, Pérez-Pardal L, Carvalheira J, Beja-Pereira A (2022) Gut microbiome studies in livestock: Achievements, challenges, and perspectives. *Animals* 12: 3375. <https://doi.org/10.3390/ani12233375>
- Godden SM, Lombard JE, Woolums AR (2019) Colostrum management for dairy calves. *Veterinary Clinics of North America: Food Animal Practice* 35: 535-556. <https://doi.org/10.1016/j.cvfa.2019.07.005>
- Gomes V, Barros BP, Castro-Tardón DI, Martin CC, Santos FCR, Knöbl T, Santarosa BP, Padilha LM, Hurley DJ (2023) The role of anti-*E. coli* antibody from maternal colostrum on the colonization of newborn dairy calves gut with *Escherichia coli* and the development of clinical diarrhea. *Animal - Open Space* 2: 100037. <https://doi.org/10.1016/j.anopes.2023.100037>
- Ha JK (2023) Leadership of AAAP scientists and journals in animal science: Achievements, limitations, and challenges. *Animal Bioscience* 36: 1-9. <https://doi.org/10.5713/ab.22.0409>
- Hang BPT, Wredle E, Dicksved J (2021) Analysis of the developing gut microbiota in young dairy calves-impact of colostrum microbiota and gut disturbances. *Tropical Animal Health and Production* 53: 50. <https://doi.org/10.1007/s11250-020-02535-9>
- Khan I, Nassar N, Chang H, Khan S, Cheng M, Wang Z, Xiang X (2024) The microbiota: A key regulator of health, productivity, and reproductive success in mammals. *Frontiers in Microbiology* 15: 1480811. <https://doi.org/10.3389/fmicb.2024.1480811>
- Klein-Jöbstl D, Quijada NM, Dzieciol M, Feldbacher B, Wagner M, Drillich M, Schmitz-Esser S, Mann E (2019) Microbiota of newborn calves and their mothers reveals possible transfer routes for newborn calves' gastrointestinal microbiota. *PLOS ONE* 14: e0220554. <https://doi.org/10.1371/journal.pone.0220554>
- Kumar M, Kumari S, Guntipally SS, Chhabra A, Kumar A, Kumar P (2024) A step-by-step guide of bibliometric study for healthcare and allied research. *Journal of Pharmacy & Bioallied Sciences* 16: S4114-S4116. https://doi.org/10.4103/jpbs.jpbs_1347_24
- Liang J, Sun Y, Yang Y, Wang Z, Wu H, Gu T, Zhang R, Sun X, Yao B, Tu T, Liu X, Luo H, Tong G, Jiao Y, Li K, Zhang J, Wu K (2025) Agricultural biotechnology in China: Product development, commercialization, and perspectives. *aBIOTECH* 6: 284-310. <https://doi.org/10.1007/s42994-025-00209-4>
- Lim WM, Kumar S (2024) Guidelines for interpreting the results of bibliometric analysis: A sensemaking approach. *Global Business and Organizational Excellence* 43: 17-26. <https://doi.org/10.1002/joe.22229>
- Lombard JE, Urie NJ, Garry FB, Godden SM, Quigley JD, Earleywine TJ, McGuirk SM, Moore DA, Branan MA, Chamorro MF, Smith GW, Shivley CB, Catherman DR, Haines DM, Heinrichs AJ, James RE, Maas J, Sterner KE, Paiva D (2020) Consensus recommendations on calf- and herd-level passive immunity in dairy calves in the United States. *Journal of Dairy Science* 103: 7611-7624. <https://doi.org/10.3168/jds.2019-17955>
- Lopez AJ, Heinrichs AJ (2022) Invited review: The importance of colostrum in the newborn dairy calf. *Journal of Dairy Science* 105: 2733-2749. <https://doi.org/10.3168/jds.2020-20114>

- Malmuthuge N, Chen Y, Liang G, Goonewardene LA, Guan LL (2015) Heat-treated colostrum feeding promotes beneficial bacteria colonization in the small intestine of neonatal calves. *Journal of Dairy Science* 98: 8044-8053. <https://doi.org/10.3168/jds.2015-9607>
- Manterola CD, Rivadeneira JD, Salgado CC (2024) Estudios bibliométricos: Una opción para desarrollar investigación en cirugía y disciplinas afines. *Revista de Cirugía* 76: 147-156. <https://doi.org/10.35687/s2452-454920240021890>
- McGuirk SM, Collins M (2004) Managing the production, storage, and delivery of colostrum. *Veterinary Clinics of North America: Food Animal Practice* 20: 593-603. <https://doi.org/10.1016/j.cvfa.2004.06.005>
- Meesters M, Van Eetvelde M, Beci B, Opsomer G (2024) The importance of developmental programming in the dairy industry. *Animal Reproduction Science* 262: 107428. <https://doi.org/10.1016/j.anireprosci.2024.107428>
- Michán L, Muñoz-Velasco I (2013) Cienciometría para ciencias médicas: Definiciones, aplicaciones y perspectivas. *Investigación en Educación Médica* 2: 104-110.
- Navarrete-Molina C, Meza-Herrera CA, Ramirez-Flores JJ, Herrera-Machuca MA, Lopez-Villalobos N, Lopez-Santiago MA, Veliz-Deras FG (2019) Economic evaluation of the environmental impact of a dairy cattle intensive production cluster under arid lands conditions. *Animal* 13: 2379-2387. <https://doi.org/10.1017/S175173111900048X>
- Oliveira OJ, Rocha ABT, Costa ACF, Espuny M (2024) Technical-scientific scenario based on the triple helix: Innovative approach beyond bibliometrics. In: Oliveira OJ (ed) *Bibliometrics - An essential methodological tool for research projects*. IntechOpen, United Kingdom. pp. 1-18. <https://doi.org/10.5772/intechopen.1007689>
- Passas I (2024) Bibliometric analysis: The main steps. *Encyclopedia* 4: 1014-1025. <https://doi.org/10.3390/encyclopedia4020065>
- Priyashantha H (2025) World dairy system sustainability: A milk quality perspective. *Frontiers in Sustainable Resource Management* 4: 1572962. <https://doi.org/10.3389/fsrma.2025.1572962>
- Puppel K, Gołębiewski M, Konopka K, Kunowska-Słószarz M, Słószarz J, Grodkowski G, Przysucha T, Balcerak M, Madras-Majewska B, Sakowski T (2020) Relationship between the quality of colostrum and the formation of microflora in the digestive tract of calves. *Animals* 10: 1293. <https://doi.org/10.3390/ani10081293>
- Quereda JJ, García-Roselló E, Barba M, Mocé ML, Gomis J, Gómez-Martín Á, Rodellar C (2020) Vaginal microbiota changes during the estrous cycle in dairy heifers. *Frontiers in Veterinary Science* 7: 371. <https://doi.org/10.3389/fvets.2020.00371>
- Ram PK, Singh SK, Srivastava A, Kumar G, Jaiswal AK, Yadav B, Garg SK (2020) Effects of injectable trace minerals (ITMs) on Th1/Th2 cytokine balance of newborn calves with tropical theileriosis. *Biological Trace Element Research* 199(4):1397-1404. <https://doi.org/10.1007/s12011-020-02263-z>
- Rodriguez-Sánchez AJ, Meza-Herrera CA, De Santiago-Miramontes A, Navarrete-Molina C, Veliz-Deras FG, Ordoñez-Morales JZ, Flores-Salas JM, Marin-Tinoco RI (2024) Circular economy, dairy cow feed leftovers, and *Withania somnifera* supplementation: Effects on Black Belly ram's libido, sperm quality, sexual behavior, and hemogram values. *Biology* 13: 656. <https://doi.org/10.3390/biology13090656>
- Silva FG, Silva SR, Pereira AMF, Cerqueira JL, Conceição C (2024) A comprehensive review of bovine colostrum components and selected aspects regarding their impact on neonatal calf physiology. *Animals* 14: 1130. <https://doi.org/10.3390/ani14071130>
- Van-Eck NJ, Waltman L (2010) Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 84: 523-538. <https://doi.org/10.1007/s11192-009-0146-3>
- Villot C, Chen Y, Pedgerachny K, Chaucheyras-Durand F, Chevaux E, Skidmore A, Guan LL, Steele MA (2020) Early supplementation of *Saccharomyces cerevisiae boulardii* CNCM I-1079 in newborn dairy

- calves increases IgA production in the intestine at 1 week of age. *Journal of Dairy Science* 103: 8615-8628. <https://doi.org/10.3168/jds.2020-18274>
- Wang D, Du Y, Huang S, You Z, Zheng D, Liu Y (2021) Combined supplementation of sodium humate and glutamine reduced diarrhea incidence of weaned calves by intestinal microbiota and metabolites changes. *Journal of Animal Science* 99: skab305. <https://doi.org/10.1093/jas/skab305>
- Zhu Y, Li Z, Yang Y, Zhan T, Bu D, Ma L (2024) Early-life *Clostridium butyricum* supplementation improved rumen development and immune by promoting the maturation of intestinal microbiota. *Journal of Agriculture and Food Research* 18: 101517. <https://doi.org/10.1016/j.jafr.2024.101517>