



# State of the art of the cow-calf systems in beef and dairy cattle (*Bos taurus*) operations in EU, USA, and Brazil from 1998 to 2023

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## ABSTRACT

Cow-calf systems represent a significant research area in animal husbandry, with differences depending on the final product (meat or milk). This study aimed to apply text mining and topic analysis on literature describing cow-calf systems in European, American, and Brazilian beef and dairy sectors between 1998 and 2023. Additionally, cow-calf contact (CCC) literature data was manually extracted. Our findings revealed the presence of 11 research areas among literature on cow-calf systems, with different priorities identified in the beef and dairy sectors. Beef industry mainly focused on animal proficiency and nutrition, while dairy on animal welfare and CCC, which showed a growing trend as emerging research topic, mostly in the EU. Current debates around calf welfare and EU's planned animal welfare legislation revision appeared to be driving the increasing interest in this topic. Studies in the beef sector were mainly localized in Brazil, showing that research in different contexts and species is important for CCC implementation. Manual data extraction showed considerable variation in the retained CCC documents regarding sample size, type of contact, methods and CCC duration. Learning about the varied CCC approaches used in beef and dairy farms in different locations, concentrating on their strengths and weaknesses, will help to develop novel solutions to global challenges. Adopting validated and robust indicators would help scientists and policymakers to monitor the system's quality. To improve CCC feasibility, match consumer demands, and move towards One Welfare and One Health, future research should focus on a variety of situations to overcome the current shortcomings.

## 1. Introduction

The economic and societal functions of livestock production have undergone significant transformations in recent years, and these changes are expected to persist and become more pronounced in the near future. Supply chains and animal research and development must adapt their strategies and goals to overcome the difficulties encountered by the beef and dairy sectors and meet consumers' demands (Brscic, 2020; Hocquette and Chatellier, 2011; Nalon and Stevenson, 2019). Cow-calf systems are crucial for animal husbandry, and they differ depending on the type of end product (meat or milk). In beef-oriented operations, cow-calf systems generally aim at producing beef calves to be fattened for the finishing phase, while in dairy, they aim at ensuring the continuity of milk production and the presence of replacement stock (Eriksson et al., 2022; Womach, 2005). While at global level, human population is expected to grow, leading to a 20 % increase in demand for

animal proteins in the agricultural market, the beef sector in different key countries is witnessing a significant slowdown (FAO, 2023, b). The reasons behind this phenomenon can be attributed to a growing awareness in regards to animal welfare, environmental sustainability, and One Health (OECD/FAO, 2021), which might have further influenced dietary preferences (Porto Costa et al., 2023). By contrast, dairy production is expected to grow over the next decade by 17 % globally (OECD/FAO, 2023). Considering the current production data available for beef and dairy sectors worldwide, the authors opt to focus on three economically relevant geographical areas: the EU, the USA, and Brazil (Vinci, 2022). In all three areas, the beef sector is marked by a deep interconnection with the dairy one, with a significant part of the beef market coming from culled dairy cows and dairy veal calves. In the EU, their presence accounts for more than half of the beef (de Vries et al., 2015); in the USA, this fraction corresponds to one-fifth of the whole commercial beef supply (Laca et al., 2023). Specialized beef breeds

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cover the remaining fraction (de Vries et al., 2015; EFSA, 2012; Laca et al., 2023). According to Eustáquio Filho et al. (2009), in Brazil, although the use of dairy calves in the beef industry has become widespread in some markets, it is thought that veal could become more popular, as it increases the income of dairy producers and makes dairy farming profitable.

Beef production consists of three main parts: pre-weaning, fattening, and finishing animals. The scientific community has widely investigated both post-weaning phases, whereas calves' handling, welfare, and health management have been addressed only in recent years (Nalon et al., 2021). For a proper evaluation of these factors, it is essential to consider the different practices applied to calves based on their origin (beef vs. dairy) as well as the internal division of calves' management in the beef sector itself (EFSA, 2023; Rotz et al., 2019).

In the three areas included in this study, the beef sector is characterized by numerous specialized breeds, where calves are typically reared with their dams in suckler cow-calf (SCC) systems. In the EU, this semi-extensive system includes an outdoor grazing phase during summer and an indoor housing during winter (Nguyen et al., 2010). The calves stay with their dams until 5 to 9 months of age, when they are weaned and moved to fattening units (EFSA, 2023). Similarly, in the USA, SCC farms are usually extensive or semi-extensive. Almost 30 % of Brazil's calves are produced in large ranches, characteristic of the Midwest (Millen et al., 2011). All the three areas present pasture-based systems, and thus heavily rely on the land's features, leading to a great diversity range in terms of animals' management, handling, and attention towards their welfare. This variety represents a strength point due to its consequentially strong connections to the local territory at an economic, societal, and environmental level (Deblitz et al., 2008; Drennan and McGee, 2009; Hessle et al., 2019; Veysset et al., 2005).

Calf rearing, in beef for meat production and in the dairy sector as replacement stock, is a consistent part of the herd management, and optimising their welfare can be very demanding. In the beef sector, it is easier to keep CCC in pasture-based systems until calf weaning. On conventional dairy farms in the EU, calves are separated from the dams within hours of birth and they are artificially fed with colostrum first and then with milk replacers and solid feed (EFSA, 2023; Ventura et al., 2013). Early cow-calf separation is commonly applied in the USA (USDA, 2016) and Brazil (dos Santos and Bittar, 2015), as well. The negative welfare consequences of this practice have been recently addressed by the European Food Safety Authority (EFSA), and recommendations were listed to contrast such effects (EFSA, 2023). Implementing prolonged cow-calf contact (CCC) systems might be challenging due to the varying characteristics of production systems. Additionally, practical and economical constraints of production and housing systems, along with farmers' concerns about potential negative health effects limit the implementation of CCC systems at a wide scale. These practices are often considered responsible for a decrease in the milk fat content and a reduction of the overall amount of saleable milk due to the calf's direct consumption. Although this effect may be offset by the potential increase in protein content reported in the milk of suckled cows, other factors also play a role, such as the structural modifications to provide calves with access to a creep area and to dedicated resources, and the legal flooring requirements for the cow-calf pair (Knierim et al., 2020). Additionally, farmers' perceptions of such systems, often concerning an increased possibility of diarrhea and respiratory diseases, need to be taken into account (Bertelsen and Vaarst, 2023; EFSA, 2023).

However, review papers and empirical studies reported that both cow and calf benefit from a prolonged contact regardless of the production sector and in particular when the debonding is well managed and they are gradually separated (Beaver et al., 2019; Johnsen et al., 2016; Meagher et al., 2019; EFSA, 2023). The calves show improved growth rates, enhanced immune response and consequently an improved health status. Moreover, they express more natural feeding, including several suckling bouts during the day, and experience learning and behavioural development including social skills and coping

strategies (Watts and Stookey, 1999; EFSA, 2023; Jensen et al., 2024; Neave et al., 2024). The cows exhibit their natural maternal behaviours and the most hedonic experience of nursing their own calf, benefitting from the oxytocin and the endogenous opioids released during sucking (Uvnäs-Moberg, 1998; Lupoli et al., 2001; Olazábal et al., 2013). This hormonal release accelerates uterus involution after parturition, lowers the incidence of retained foetal membranes (Krohn et al., 1990), and reduces the risk of mastitis due to lower amounts of milk remaining in the udder (Krohn, 2001; Flower and Weary, 2003).

The different characteristics and management practices of the SCC systems in the EU, USA, and Brazil can yet lead to the identification of some shared common points. A potential way forward to identify their shared similarities and differences is by analyzing the scientific literature through text mining and topic modelling methods. Text mining is usually applied to extract information from textual material using specialized approaches (Munaf et al., 2023; Nalon et al., 2021). Its use, along with topic analysis, can reveal hidden structures in big data sets or concepts, revealing recurring motifs and unexpressed themes, simplifying analysis at the same time. Several studies applied such a combined approach in veterinary research on topics related to epidemiology, animal welfare, and others (Furrer et al., 2015; Munaf et al., 2023; Nalon et al., 2021). To the best of the authors' knowledge, no study applied text mining and topic modelling on a multidimensional topic such as the cow-calf system to identify specific areas of interest in the current scientific literature. This contribution aims to compare the state of the art of the cow-calf systems in European, American, and Brazilian beef and dairy sectors, highlighting overlapping traits and disruptive contrasts with a specific focus on CCC as a trending area of concern.

## 2. Materials and methods

### 2.1. Corpus creation

The research was conducted in March 2024. Two-fold scientific literature researches were conducted using the Scopus® database of Elsevier©. The first research was conducted according to a protocol developed to identify peer-reviewed documents on the topic "cow-calf operations" in the beef and dairy sectors published in the timespan from 1998 to 2023 and presenting at least title and abstract in English. The scientific literature search protocol was based on the following search queries: "beef AND cow-calf", "dairy AND cow-calf", "animal AND welfare AND cow-calf", "management AND cow-calf", "peripartum AND beef", "peripartum AND dairy", "pasture AND cow-calf", "biosecurity AND cow-calf", "nutrition AND cow-calf", and "cow-calf". The geographical areas included in this study were limited to EU, USA and Brazil, which were selected on the basis of their leading position in terms of beef production (USA and Brazil) (FAO, 2024) and of milk production (EU) (USDA, 2024). The localization of each document was performed based on the affiliation of the first or corresponding author (Nalon et al., 2021; Trapanese et al., 2024).

Regarding the timespan, 1998 was selected as baseline year based on both the European and American legislations related to calves' welfare for veal production (Council Directive 98/58/EC, 1998; H.R.696, 1997). In the same year, the Brazilian Federal Law n. 9.605 of 1998 provided the general guidelines on the protection of environment and animals (Presidência da República do Brasil, 1998) and the ordinance 907/2017 created the permanent technical commission on animal welfare (CTBEA) with the objective of coordinating actions on the welfare of farm animals and of economic interest in the various links of the livestock chain (Ministério da Agricultura Pecuária e Abastecimento, 2017).

The documents retrieved from the first search were then refined to include only the subject areas related to Agricultural and biological sciences, Veterinary, and Environmental science; to exclude all document types different from original research, reviews, and conference proceedings/paper; to exclude papers lacking of title and abstract in English.

Each search query led to the selection of a list of documents, whose information were extracted and organized in an Excel spreadsheet (Microsoft Excel®, v16.0) as a 2-way table reporting the documents in rows (one record per row) and the descriptive information in columns.

At the end of the collection phase, all datasets were merged. The documents were manually screened: duplicate records, documents lacking relevant information such as author, source, or document type were removed as well as “erratum” document type. A co-author (EDV) manually screened all titles and abstracts for coherence with the research topic. Additional exclusion criteria in the manual screening were related to meeting one of the four characteristics: 1) study objective dealing with perceptions of stakeholders of the livestock sector or of the general public (e.g. surveys and research questionnaires); 2) geographical localization of first or corresponding author affiliations to research providing organization (research institute or academic institutions) located outside the EU, the USA or Brazil; 3) topic not pertinent to the current study; 4) animal species/breed different from *Bos taurus*.

The final resulting dataset (see Supplementary Material S1) was split in two sub-datasets according to production in records related to cow-calf systems in the beef and in the dairy sector. Documents that included both beef and dairy sectors were counted twice in both datasets. Data were submitted to descriptive statistical analysis to profile the scientific corpus in terms of number of records published per year and of number of citations per document per year.

## 2.2. Text mining

Text mining was performed to convert text data into numeric information and to highlight the word frequency distributions following the methodology described by Nalon et al. (2021). The frequency of the words extrapolated from the corpus of papers represents an objective and verifiable data. The analysis was conducted on the abstracts of the papers in the final dataset using R package (2023), using a combination of the functions of the packages ‘*tm*’, ‘*tidyverse*’, ‘*SnowballC*’, ‘*ggplot2*’ and ‘*dyplr*’.

The text pre-processing consisted in three steps: tokenisation, filtering and stemming (Nalon et al., 2021; Sebastiani, 2002; Vijayarani and Janani, 2016). The main keywords used for the bibliographic search (and related synonyms) were removed to avoid poor discriminative information due to their presence in almost all the abstracts retrieved (Provalis Research, 2021). The removed words were: “cow”, “cows”, “calf”, “cowcalf”, “calves”, “calving”, “cattle”, “heifer” and, finally, “dairy” and “beef” respectively for the homonymous dataset of each. Stemming reduces word variants to their root form (stem) by removing their suffix, thus allowing the identification of the same word even when presenting different grammatical forms (example: “separ” is the root of the words “separation”, “separating”, “separated”, and so on). In this way, the variability and sparseness of the results are reduced; for these analyses, this feature was performed through the Porter stemming algorithm (Hvitfeldt and Silge, 2021).

The words were then organized into a matrix presenting the documents along the rows and the terms along the columns, the so-called “document term matrix” (DTM). A Term Frequency-Inverse Document Frequency (TFIDF) technique was used to attribute a relative weight to words (Salton and Buckley, 1988). This parameter represents the frequency of a term adjusted for how widely it is used, thus reflecting how important a word is in the whole collection of documents.

Production sector specific, the 50 stems (words without suffix) with the greatest relevance were represented as wordclouds (TFIDF  $\geq 1.229$  for beef; TFIDF  $\geq 0.376$  for dairy). The wordclouds were created through the website <https://www.wordclouds.com/> and represented the terms in a font-size directly proportional to the related TFIDF value.

## 2.3. Topic modelling

Topic modelling is a statistical technique that uses an algorithm to analyze a collection of documents from multiple perspectives, uncovering the most relevant semantics and clustering the main themes as topics (Kherwa and Bansal, 2019). It is described as an unsupervised machine learning technique that allows the discovery of semantic connections hidden in documents, or in general textual data, in the form of a topic (Egger, 2022; Snyder, 2015). A single topic can be described as a multinomial distribution of words, while a multinomial distribution of latent topics can describe a single document (Nalon et al., 2021). An example of this can be represented by Zuliani et al. (2021), a text-mining review analyzing the topics and trends in mountain livestock farming over four decades, which contributed to a deeper understanding of its current and future challenges.

For this study, the latent Dirichlet allocation (LDA) function, together with the Gibbs sampling option of the *topicmodels* package in R, were used (Egger, 2022; Grün and Hornik, 2011). Since it was necessary to establish independently the number of topics per each DTM, models with several different numbers of topics were fitted. In particular, for the beef database, consisting of 181 records, the attempts were made with 6, 7 and 8 topics; for the dairy dataset, containing a smaller amount of records (54), the attempts were made with 5, 6 and 7. At the end of this trial-and-error process, the number of topics identified was 6 for the beef database, and 5 for the dairy one. Finally, the models were validated through the calculation of the following functions: log likelihood (LogLik) and perplexity, key metrics for evaluating and comparing models. The former measures how well a probabilistic model (like a topic model) explains the observed data, whereas the latter measures how well the model predicts new data, making it a metric more focused for assessing generalization (Contiero et al., 2019). For the models’ validation, the results of both metrics were taken into account to establish their proper fit. Finally, the topics were visualized as bar histograms, with every bar corresponding to a specific term, and whose length was proportional to the word’s probability within the topic (beta value). Finally, 3 co-authors (EDV, IAD, CM) individually developed a title per each topic based on the words assigned. The labels were blindly sent to a co-author (MB) to compare them and to select the most appropriate ones by general consensus.

## 2.4. Data extraction on cow-calf contact

An additional search was undertaken using Scopus® to extract data in the specific context of CCC. For this purpose, the terms “animal welfare” and “cow-calf” were employed. Exclusion criteria were the same used in the text mining approach, and documents that were not relevant to the topic of CCC were excluded from this analysis as illustrated in Fig. 1.

Full texts of eligible records were examined to categorize each document based on the type of study (methodological; research; interview/questionnaire; review; perspective/position/debate/research reflection), scenario, production type (beef; dairy; general), and its application in organic farms (adapted from Brscic et al., 2021).

After an initial agreement between co-authors, one assessor (IAD) screened all the documents and filled out a shared Excel document to ensure a consistent evaluation and data-gathering process. Supplementary Material S2 includes the full list of retained records. The texts were examined further according to the provision of the definition of CCC (yes/no) or reference to a citation (yes/no). In case referring to a citation, the reference was also recorded.

To have a better understanding of the various terminology full texts were also reviewed to extract “other general terms” used as synonym/definition of the CCC. These terms were manually searched according to their frequency of mention in the full texts of the publications included in the study, excluding references.

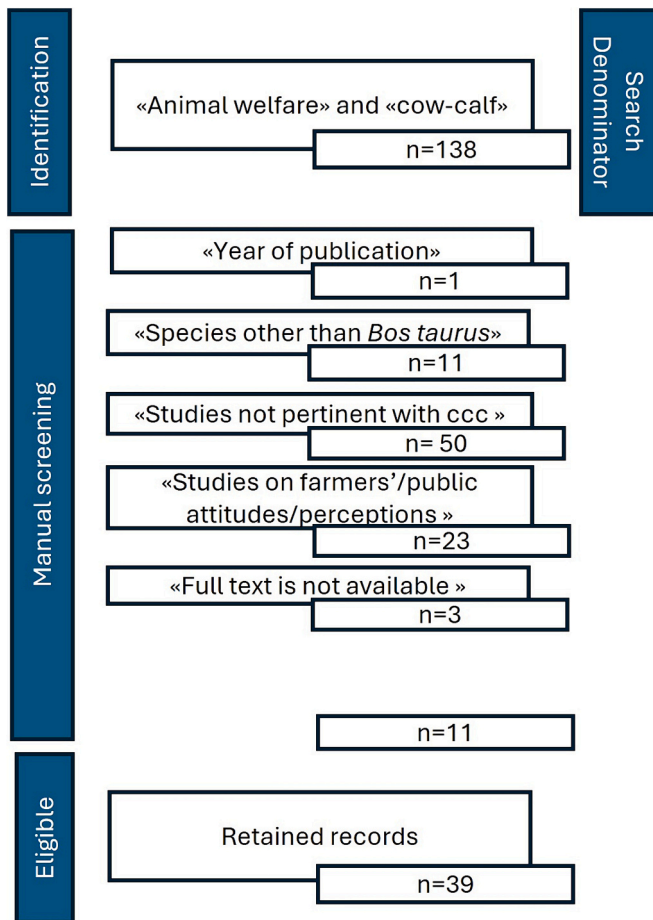


Fig. 1. A flowchart that illustrates the search protocol.

### 3. Results

The main dataset covering cow-calf systems from 1998 to 2023 was divided into two smaller datasets: one related to the beef sector containing 182 documents, and the other related to the dairy sector containing 55 documents, of which five belong to both sectors. The yearly distribution of the number of documents and the average number of citations per document according to the sector are provided in Fig. 2.

Studies on cow-calf systems showed a steady increase over the years and the beef cattle documents are generally more dominant than dairy

ones. The last three years (2021-2023) presented a growing interest towards dairy systems, with a parallel decrease of the number of studies on beef. In the considered time span, the largest contribution to the literature in the beef sector was made by US research providing organizations ( $n = 137, 75\%$ ), followed by the EU ( $n = 32, 18\%$ ) and Brazil ( $n = 13, 7\%$ ). Studies on dairy cattle started in the EU during 2002, with a rising trend ( $n = 49, 89\%$ ). Studies on dairy cattle in the USA ( $n = 5, 9\%$ ) have increased in the last two years, and the only study conducted in Brazil (2%) dates back to 2013.

#### 3.1. Text mining and topic modelling

Text mining analysis was performed to identify the stems of the words that appeared most frequently in the data corpus according to the production sector. The pre-processing of the data produced 2852 stems in the documents regarding the beef sector, and 1454 stems were retained after sparseness reduction (excluding words that made up less than 1% of the corpus). The application of the same procedures to the dairy documents produced 1497 and 1497 items, respectively. In this case, the correspondence between the number of stems pre- and post-sparseness reduction is due to the absence of items that made up for less than 1% of the whole corpus. Results representing the most relevant stems are shown as word clouds in Figs. 3 and 4. Most of those main word stems shown in Figs. 3 and 4 are also included in the topics identified after LDA analysis, and therefore they will be discussed below.

Results of the topic modelling representing the ten most relevant words per topic in the LDA and the labels finally assigned to each topic in the beef and dairy datasets, along with the corresponding number of documents are presented in Fig. 5 (beef) and Fig. 6 (dairy). The difference in number of topics, that was 6 for beef and 5 for dairy, is related to the size of the two datasets.

#### 3.2. Data extraction on CCC

During the text mining and topic modelling process, CCC was identified as one of the emerging areas in the cow-calf systems. Based on the search schematically represented in Fig. 1, 39 documents (28%) were retained and their distribution over time showed that the first publication was in 2002. Fig. 7 shows the yearly distribution of the number of documents and the mean number of citations per document by sector. Out of the 39 documents on CCC, 8 of them were related to the beef and 34 of them to the dairy sector. Three documents were categorized within both sectors, making a total of 42 documents. Considering the sector distribution across geographical areas, European research providing organizations contributed with 3 documents on beef and 32 on dairy, while the Brazilian ones contributed with 5 documents on beef. The only

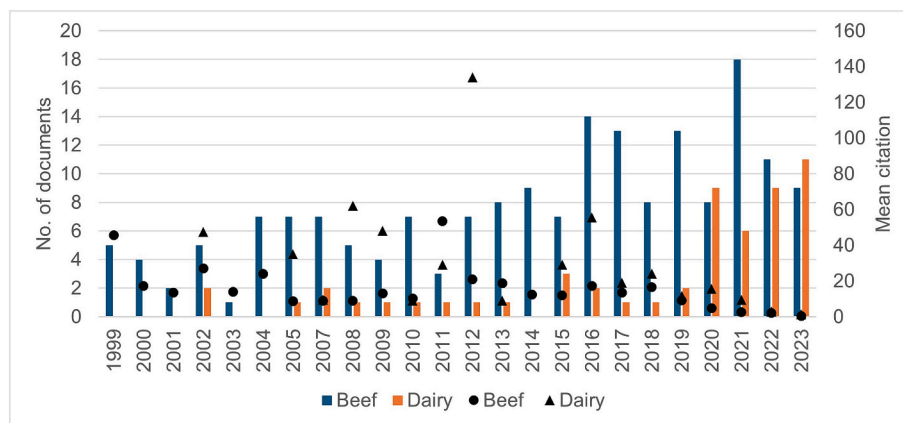


Fig. 2. Number of beef and dairy documents per publication year (left axis, bar graph) and their corresponding mean number of citations per document per year (right axis, dot graph) retrieved for the text mining and topic modelling analysis.



Fig. 3. Cloud representation of the most relevant stems in the database related to the beef (TFIDF  $\geq 1.229$ ) sectors. The greater relative frequency of the words is reflected by their greater size.



Fig. 4. Cloud representation of the most relevant stems in the database related to the dairy (TFIDF  $\geq 0.376$ ) sector. The greater relative frequency of the words is reflected by their greater size.

American contribution to the CCC topic in the dairy sector was represented by a document actually shared by both European and American research providing organizations.

The journals in which more than one document on CCC had been published were Applied Animal Behaviour Science ( $n = 10, 26 \%$ ), Journal of Dairy Research ( $n = 9, 23 \%$ ), Animal ( $n = 3, 7 \%$ ), Journal of Dairy Science ( $n = 2, 5 \%$ ), and Animals ( $n = 2, 5 \%$ ), respectively. In terms of frequency distribution of study type, research documents ( $n =$

23, 59 %) were followed by perspective/position/debate/research reflection documents ( $n = 10, 26 \%$ ) and reviews ( $n = 6, 15 \%$ ), respectively. Document classification according to scenario, showed that the most frequent one was on farm ( $n = 22, 56 \%$ ). Only five documents considered or described the research conducted in organic farming systems and they were from dairy systems in Europe.

The term ‘‘cow-calf contact’’ or ‘‘CCC’’ was mentioned in 24 (61,5 %) documents included in this study. The CCC concept definition was provided in six documents. Two documents included the authors’ own definitions (Sirovnik et al., 2020; Waiblinger et al., 2020). Five included a reference to Sirovnik et al. (2020), and one to Newberry and Swanson (2008) and Johnsen et al. (2015) for CCC definition. In two documents CCC was not defined but there was a reference to Sirovnik et al. (2020). Fig. 8 represents the frequency distribution of other general terms related to CCC retrieved from the retained documents. Other terminology frequently used in the retrieved documents was represented by the following words or roots: foster (number of documents = 17), maternal behaviour (13), affiliative behaviour (10), bond (27), nursing (20), stress (35), mother-offspring (4), weaning (32), rearing (31), and suckling (30).

Detailed research of the CCC characteristics in the retained documents showed variation on contact duration from one day to six months, and different types of contacts. The treatment sample size in these documents varied between 6 and 42 cow-calf pairs within a total group size varying from 28 to 70 pairs. Some studies reported only the number of calves which varied between 38 and 844 calves.

#### 4. Discussion

The dataset from 1998 to 2023 on cow-calf systems, focusing on beef and dairy sectors showed that beef cattle documents were more dominant in recent decades. Although, in the last three years, the interest for the dairy systems has increased, while beef studies decreased. The largest contribution to literature in beef was made by American research providing organizations, followed by Europeans and Brazilians. Studies on dairy cattle began in 2002, with a rising trend and mostly conducted by research providing organizations in Europe. These trends may reflect the main production types in the geographical areas and the research interests that are changing according to the emerging topics in cow-calf systems.

Text mining proved to be a good method to extract the most frequent words’ stems and the subsequent application of the topic modelling allowed their clustering. Although their application in literature is still limited, this strategy allowed to perform a comprehensive analysis of a large number of documents (Asmussen and Møller, 2019). On the contrary, manual screening, which is characterized by extensive research and time-consuming analyses, can be performed only on a limited number of documents (Snyder, 2015). When the differences between the beef and dairy sectors were evaluated through text mining and topic modelling analysis, it was clear that there was more focus on animal proficiency and nutrition in the beef, and animal welfare and cow-calf relationship in the dairy sector. These results are in accordance with the themes emerged from the topic analysis, where calf performance stood out in the beef sector and cow efficiency in the dairy one, likely reflecting the economic interests of the respective categories (Michaličková et al., 2014; Notter, 2002). In the dairy sector, a specific topic emerged from the modelling that the authors labelled as animal welfare. Its lack in the beef sector is likely due to less research conducted on beef cattle welfare compared to dairy, or alternatively, if present, it was not focused in the cow-calf systems. This consideration is partially confirmed by the literature, where most welfare studies on the beef sector are related to practices conducted during post-weaning phases, such as dehorning, castration, and the consequences of abrupt weaning (Canozzi et al., 2017; Cozzi et al., 2015; Enriquez et al., 2011).

It is noteworthy that the peak mean number of citations was reached in 2012, largely due to the high number of citations of a single document

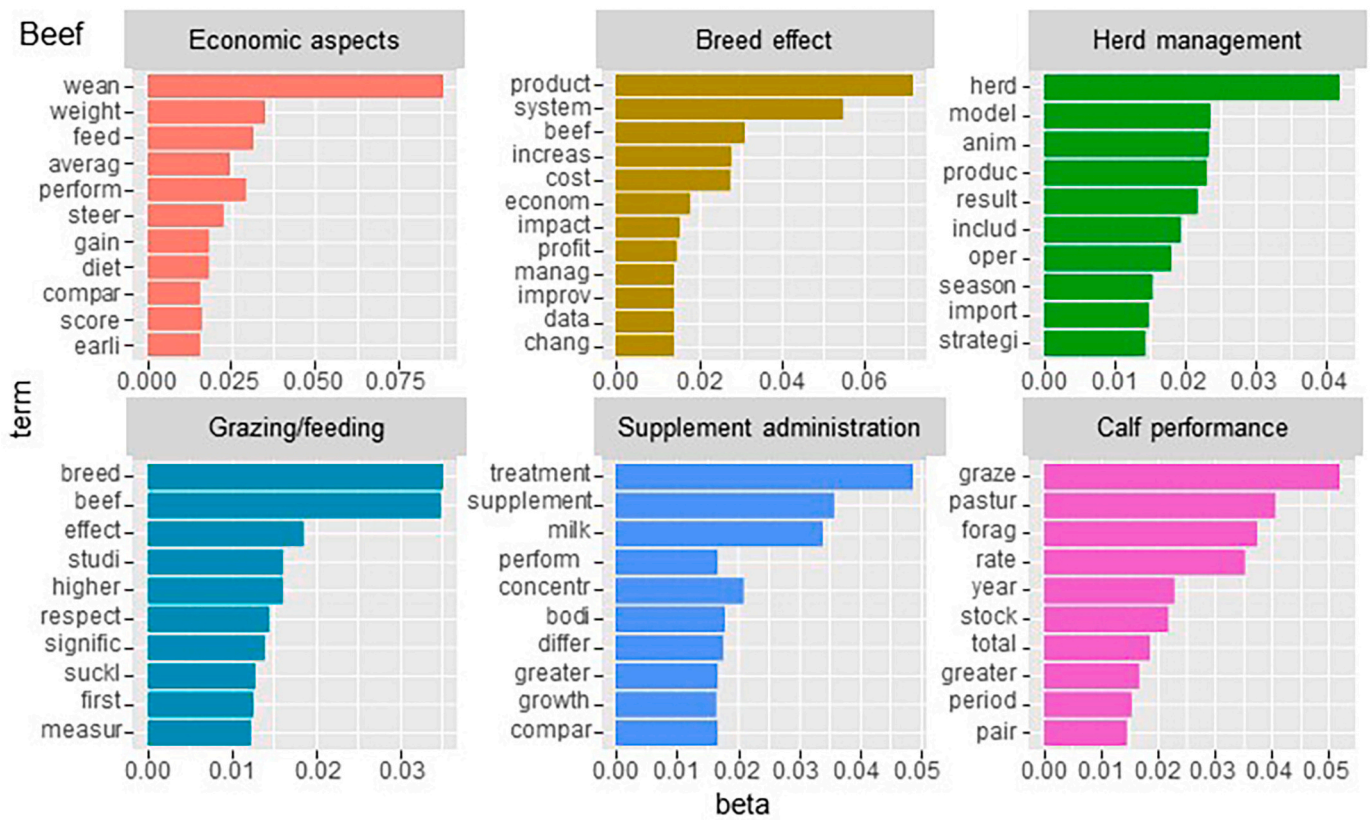


Fig. 5. Histograms representing the ten most relevant stems per topic in the latent Dirichlet allocation relative to the 182 beef sector documents (beta = probability that a word belongs to a given topic).

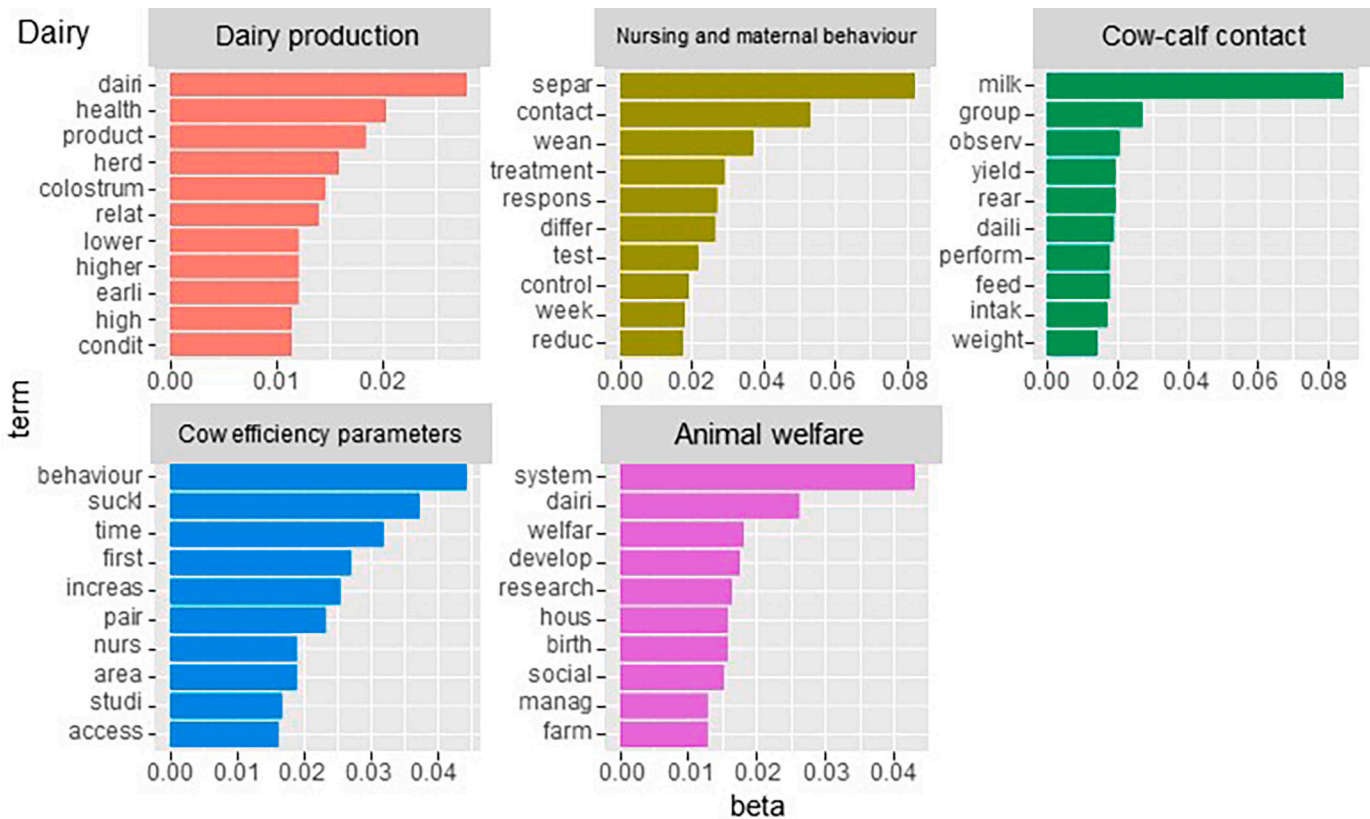


Fig. 6. Histograms representing the ten most relevant stems per topic in the latent Dirichlet allocation relative to the 55 dairy sector documents (beta = probability that a word belongs to a given topic).

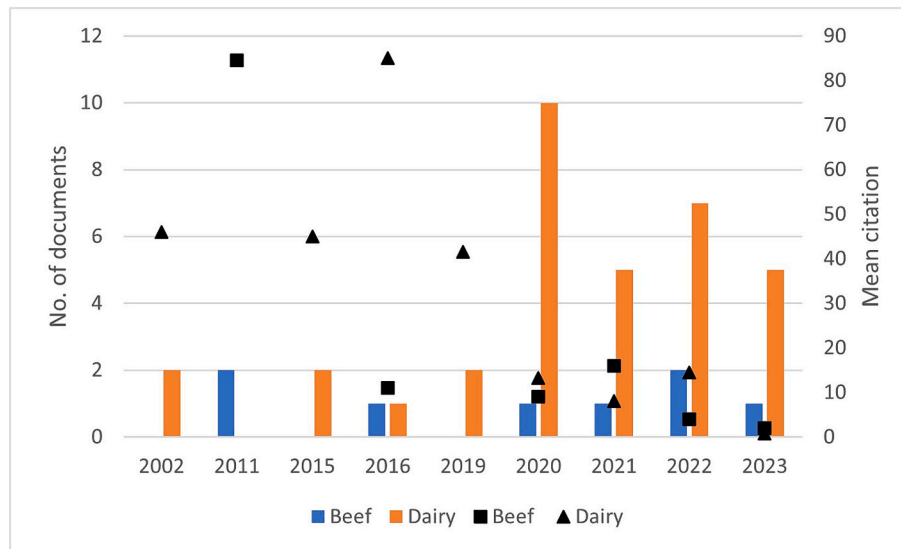


Fig. 7. Number of beef and dairy documents on CCC per publication year (left axis, bar graph) and their corresponding mean number of citations per document per year (right axis, dot graph) retrieved for the manual direct screening.

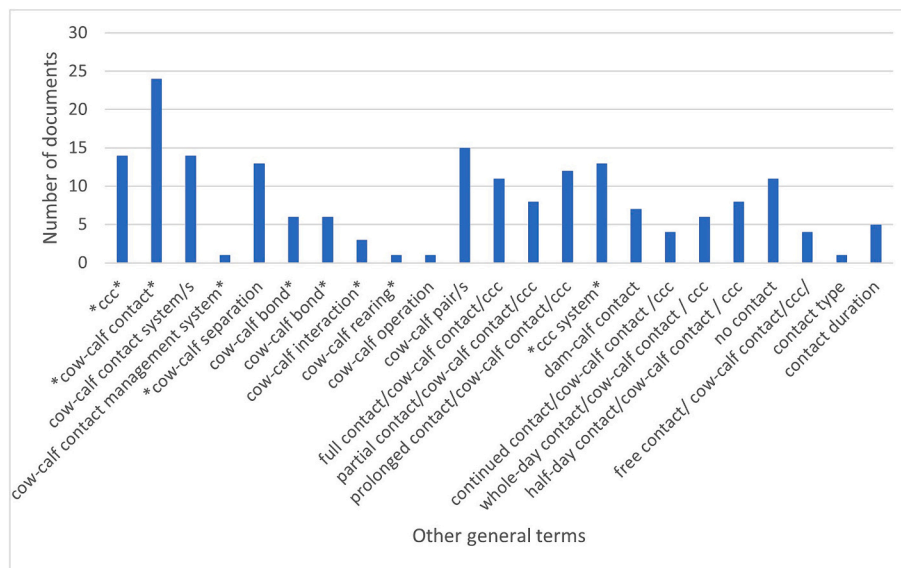


Fig. 8. Frequency distribution of other general terms related to CCC retrieved from the 39 retained documents.

by Jensen (2012), dealing with cow maternal behaviour. The latter document was cited over 130 times, culminating in a notable success in, 2021. In this year the public citizen initiative “End the Cage Age” spurred the European Commission to commit to a revision of the existing animal welfare legislation for several farm species. The Commission gave the mandate to EFSA to produce updated scientific opinions that can serve as a basis for new legislation and this covered calves. The EFSA opinion on calves included considerations and recommendations about cow-calf contact (EFSA, 2023). The first document on CCC dates back to 2002, showing that it is a relatively new research area that has been getting more attention only recently. From results of the current review, it seems evident that this topic, in relation to the dairy sector, is mainly studied in European research providing organizations, compared to America and Brazil. This does not mean that CCC is among the priority topics to be addressed in the upcoming revision of the legislation, although it is highly relevant for the future challenges that are faced at global level: 1) animal welfare and their preferred resources and social situations where they exhibit their motivation and agency; 2) human

welfare, including the freedom to have access to healthy food with full transparency about the production system from farm/field to fork; 3) environmental, economic, and social sustainability bridging production and consumers’ demands for food with added ethical value. The presence of only one American contribution to the dairy sector in the CCC documents is probably a straightforward reflection of the present implementation of alternatives to the early cow-calf separation in the United States, described as unrealistic and not fully feasible by Hanson (2023). Another potential explanation could be related to the implementation of CCC in specific geographical areas that are not necessarily represented in the current study. Furthermore, alternatives to the early cow-calf separation are adopted around the world, but they are not defined as CCC (Beaver et al., 2019; Johnsen et al., 2016; Meagher et al., 2019).

On the contrary, the overall cow-calf system documents demonstrate a clear prevalence of studies undertaken by US and Brazilian research providing organizations in regard to the beef industry, which is consistent with regional production and trade trends. The detailed analysis of

studies on CCC conducted on beef cattle, which were mainly localized in Brazil, is important to gain relevant information for future research in different contexts. In regions similar to Brazil, that primarily rely on pasture-based cow-calf systems and maintain CCC for long periods, it may also be possible to record and evaluate animal-based measures and observe cow-calf behaviour in more natural settings compared to CCC in the industrialized dairy sector. Research on other species, such as zebu and other mammals, which was excluded based on the study's species criteria, may also hold potential input for future CCC implementation. Taking into account European and American differences in cow-calf systems in the beef sector, which are linked to environmental, genetic, and typical production areas, it is strongly believed that an increase in studies dedicated to this field of animal science can make significant contributions to the development of CCC research.

The retrieved documents, that were manually screened in the second stage of this review, reported various methods of application of CCC in the dairy sector, as well as different ways to assess animal behaviour and health, and to record production traits, but they shared a common perspective on the appropriate methodology and terminology to be used in studies on this subject (De Oliveira et al., 2020; Sirovnik et al., 2020). However, it is notable that these studies were strictly related to the definition of CCC and excluded all other papers where alternatives to the early cow-calf separation are applied (e.g. Jensen, 2012) or their potential application is discussed (e.g. Brombin et al., 2019). On the one hand, the CCC definition developed once there was a reasonable amount of research on this topic. As acknowledged in the paper by Sirovnik et al. (2020), it occurred during several initiatives and in particular a scientific workshop in 2019. Whereas the interest in maternal behaviour of dairy cattle is much older than the first paper mentioning the concept of allowing prolonged cow-calf contact in this sector. On the other hand, it seems evident that CCC literature does not completely cover all the non-conventional systems that allow the prolonged expression of maternal behaviours and cow-calf bonding. Indeed, even the mostly cited paper related to the cow-calf behaviour (Jensen, 2012) was not present in our CCC dataset. We can thus suggest that, to overcome this weak point, it is essential to include additional keywords in the search strings to retrieve relevant documents dealing with alternatives to the early cow-calf separation. This applies in particular when selecting animal welfare measures that could allow a robust discrimination between good versus poor quality CCC management (Manfrè et al., 2024), ideally from birth to weaning and including the phases of debonding and separation. Identification and validation of positive welfare indicators still represents an ongoing issue (Keeling et al., 2021). However, the adoption of validated and robust indicators would shed light on the path to be followed by scientists and policymakers in both beef and dairy sectors in the upcoming years.

All the documents related to organic farming included in the dataset were attributed to European research providing organizations. From the policy perspective, organic farming may be regarded as a systemic approach for enhancing animal welfare (European Commission, 2022), even if neither the EU nor the USA legislation on organic farming provide any specific guidelines for the rearing of calves. The organic livestock and poultry production legislative act in USA allows the rearing of youngstock individually until weaning, providing them enough space to turn around, lie down, stretch out, get up, rest, and groom themselves. Additionally, dairy young stock cages should allow animals to see, smell, and hear their conspecifics and no operation may confine young cattle after weaning (NOP, 2023). This is in line with the EU animal welfare regulation (Council Directive, 2008) that currently does not align with the recommendations by the EFSA's scientific opinion (EFSA, 2023). However, the adoption of these recommendations is very challenging for farmers in terms of lack of dedicated infrastructures and fixtures and of best practice guidelines (Jensen and Tolstrup, 2021; Nawroth and Rørvang, 2022; EFSA, 2023) that can support them to upgrade their farms to more animal-friendly facilities meeting needs of several: animals, consumers and citizens, and stakeholders. In this context,

consumers with different food attitudes largely oppose the practice of abrupt early calf-cow separation at birth because it is viewed as harmful to cow and calf (Ly et al., 2021). In Europe, 60 % of consumers are willing to pay more for animal welfare-friendly products and only 26 % and 6 % of them are willing to pay respectively for up to 5 % and 20 % more for this added ethical values (Special Eurobarometer 533, 2023). Moreover, there is also high level of misinformation that is delivered to lay citizens (Čechmánek, 2024; Vettori et al., 2019), mainly through media, making them confused about making appropriate nutritional choices.

Results of the current study showed a large variation in the retained CCC documents in terms of sample sizes, CCC durations, and applications. This has already been emphasized in the literature. In particular, the level and duration of physical contact between cow and calf can vary significantly in CCC systems (Johnsen et al., 2016). As shown by the results of this study where stress was a frequent term found in 35 of the retrieved CCC documents, it seems evident that several scientific papers focused on stressful situations such as abrupt interruption of the cow-calf bond (Weary et al., 2008). Other words that are worth mentioning were weaning and rearing which were also focus of previous studies (Stěhulová et al., 2008; Wenker et al., 2022a). Within the scope of CCC studies, real improvements in the rearing of calves with their mothers until complete weaning in a more welfare friendly and nature-based way will require workable systems that will contribute to One Welfare, thus being practical for producers (Brombin et al., 2019; Weary et al., 2008). Therefore, optimization of the time of daily contact and the appropriate age for permanent separation needs more research to be established (Sirovnik et al., 2020; EFSA, 2023). To find the best alternatives in practice and understand how CCC can be implemented and disseminated on a broader scale, further data is needed to comprehensively elucidate the short- and long-term correlations between CCC systems and animal welfare attributes. In the dairy sector in particular, there is also a need for the estimation of the long-term economic impact of the different CCC systems to promote feasible and welfare-friendly economic-based decisions (Alvåsen et al., 2023; EFSA, 2023; Neave et al., 2022).

The CCC studies document a diverse range of housing systems for cows and calves (Bertelsen and Vaarst, 2023; Eriksson et al., 2022; Proudfoot, 2019; Wenker et al., 2022b), and the complexity of housing cows and calves together presents a challenge in CCC research, with numerous factors influencing success (Cook and von Keyserlingk, 2024). Information on cattle's cognitive ability remains scarce and current commercial housing systems and management procedures may only partially adapt to cattle's behavioural and cognitive repertoire (Nawroth and Rørvang, 2022). Furthermore, there is limited knowledge regarding dams' allocation of time to various activities (such as standing, grazing, and lying), as well as the duration of time they spend with their calves on pasture (Hellström et al., 2023). Additionally, early postpartum housing and calving areas will need to be modified to increase CCC where cows and calves may express their full natural potential and agency (Špinková and Wemelsfelder, 2011). Lack of best practices guidelines and dedicated facilities is regarded as a vulnerability in the current housing and management of dairy herds, not only in the EU but globally as well (Cook and von Keyserlingk, 2024; Vaarst et al., 2020).

In Europe, there are studies on the availability of various CCC practices on commercial farms (Eriksson et al., 2022; Vaarst et al., 2020). However, many European countries do not record information on these practices in their common databases, making it difficult to monitor and offer information on the current overall situation across the EU. Learning more about the variety of CCC practices used on both beef and dairy farms in different regions, focusing on the strengths and flaws of the systems from different perspectives (i.e., producers, scientists, and economists), would aid in the development of new solutions to common challenges in CCC systems worldwide (Eriksson et al., 2022). To expand existing knowledge on the subject, the use of a common nomenclature and further investigation in the field will be extremely beneficial for



developing systems that address the CCC issue when collecting information for shared databases.

To accurately understand our findings, it is important to acknowledge the inherent limitations of the methods that were used. Firstly, all the search types in this study were restricted to a single database, specifically Scopus®, which means that certain records published in journals not included in it may have been overlooked. Additionally, particular specified criteria were established a priori, before initiating the search, notably the limitation to records written exclusively in English and geographical interest. Furthermore, the implementation of the screening criteria may have led to a partial decrease in the number of records that underwent comprehensive analysis. It is crucial to emphasize that in the text mining and topic modelling approaches of analysis, only the titles and abstracts of the 237 records were considered, not the complete content. Yet, it is essential to highlight that the employed methodology may not have uncovered alternative subjects that could be more recent or less scientifically significant. Only text mining and topic modelling were conducted on the larger dataset, while other statistical evaluations, including cluster analysis, were not undertaken due to the limited number of retained documents.

## 5. Conclusion

The present study conducted a comprehensive analysis of the literature pertaining to the most recent developments in cow-calf systems across the European Union, the United States, and Brazil. It has been determined that there are at least 11 distinct areas of research related to the cow-calf systems that have been explored to varying degrees during the past 25 years. An area of particular emphasis was CCC, which is both a developing consumer concern and a subject of research. This rising interest appears to be tied to ongoing arguments around calf welfare and the approaching legislative processes. To establish legislation that promotes calf welfare, it is crucial to rely on more research. Therefore, it is advisable to do additional studies to improve the feasibility of CCC to a larger extent to meet consumers demands, guaranteeing One Welfare and One Health.

## Authors contributions

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Supervision: Marta Brscic, Claudio Forte.

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## CRedit authorship contribution statement

**Isil Aytemiz Danyer:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Elena Diaz Vicuna:** Writing – review & editing, Writing – original draft, Formal analysis, Data curation. **Claudia Manfrè:** Writing – review & editing. **Barbara Contiero:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation. **Claudio Forte:** Writing – review &

editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Marta Brscic:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Funding acquisition, Conceptualization.

## Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Project financed by the Italian Ministry of Education, Universities and Research PRIN 2022 Brscic grant 2022YNENCK entitled “The Caring Dairy: promoting prolonged cow-calf contact in nature based animal production systems”. Marta Brscic is serving as reviewer for the journal that we are submitting to. She declares there are no conflict of interests. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.rvsc.2024.105398>.

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