Research article

Scientific literature on Conjugated Linoleic Acid (CLA) research in ruminant products: A bibliometric study of evolution and current trends

Nursaadah Syahro Fitriyah[1,2], Lukman Abiola Oluodo[1,2,4], Patipan Hnokaew[2], Siriporn Umsook[2], Tanakorn Tanukarn[2], Wiphawan Kueamanee[2], Prayad Thirawong[2,3], Trisadee Khamlor[2] and Saowaluck Yammuen-Art[2,*]

[1]Graduate Program in Faculty of Agriculture, Chiang Mai University Under the CMU Presidential Scholarship, Chiang Mai 50200, Thailand
[2]Department of Animal and Aquatic Science, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand
[3]Department of Animal Science, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University, Nakhon Pathom 73140, Thailand
[4]Outreach Department, Rubber Research Institute of Nigeria, Benin City 1069, Nigeria.

Abstract

The objective of this study was to analyze the trends in ruminant products research (beef, goat, lamb, and milk) research, particularly conjugated linoleic acid (CLA) using intellectual and conceptual structures in bibliometric analysis. This study was conducted due to limited bibliometric articles despite the ongoing interest in the field. Data was extracted from the Scopus database and visualized using *VOSviewer* and the *bibliometrix* R package. The analysis was conducted on 2725 articles published between 2014-2024. The results indicate a decrease in the annual growth of publication in CLA research on ruminant products. Despite this decline, certain key journals persist in their role as primary references for CLA in ruminant products. The analysis revealed predominant topics such as fatty acids, meat quality, and biohydrogenation. However, certain emerging topics, including the application of particular feedstuffs and feed additives to boost fatty acids and CLA levels, have not been thoroughly investigated.

Keywords: Bibliometric, CLA, Ruminant products

*Corresponding author: Saowaluck Yammuen-Art, Department of Animal and Aquatic Science, Faculty of Agriculture, Chiang Mai University, Chiang Mai 50200, Thailand. E-mail: saowaluck.y@cmu.ac.th.

INTRODUCTION

Research interest in conjugated linoleic acid (CLA) production has emerged since the compound was identified as an anti-carcinogenic agent by Pariza and Hargraves (1985). CLA is a unique long-chain fatty acid produced by ruminants during the biohydrogenation process in the rumen. There are numerous CLA isomers, but it is commonly represented by two beneficial isomers: the *cis*-9, *trans*-11 C18:2, and the *trans*-10, *cis*-12 C18:2 (Salsinha et al., 2018). These compounds have been attributed to various advantages alongside acting as an anti-carcinogenic agent, such as body fat reduction and protection of cardiovascular function (Rodrigues et al., 2014). Eventually, a substantial amount of research has been conducted to increase the CLA content in ruminant products (beef, goat, lamb, and milk) by altering the diet and supplementing oils rich in PUFAs (Nudda et al., 2006; Luna et al., 2008; Rodrigues et al., 2014; Schettino et al., 2017; Mazareei et al., 2024) El-Nor and Khatab, 2012. Apart from utilizing oils, several trials examined the effect of supplementing CLA-producing bacteria isolated from rumen fluid or probiotics on CLA concentration in products (Maragkoudakis et al., 2010; Shivani et al., 2016; Zhang et al., 2024). Several studies have examined the influence of the feeding system and grazing time on CLA content in milk (Avondo et al., 2008; Tudisco et al., 2014) and the age of slaughter on the meat quality of lambs (Cougo et al., 2024).

However, extensive studies on the increase of CLA concentration in ruminant products are dispersed. Following this, bibliometric analysis is a quantitative and statistical approach suitable for managing enormous amounts of unstructured scientific data (Ghassemi Nejad et al., 2023) related to this subject of study. This technique is appropriate to identify emerging trends, research gaps, and current issues on a specific research scope to construct a scientific map. Furthermore, uncovering the emerging trends in article and journal performance, collaboration patterns, and research constituents, and exploring the intellectual structure of a specific domain in the literature enable scholars to gain a comprehensive overview, identify knowledge gaps, derive novel ideas for investigation, and position their intended contributions to the field (Donthu et al., 2021). Bibliometric studies provide more reliable and objective analysis for deciphering and mapping the cumulative scientific knowledge and development of established disciplines, thereby fostering novel and significant advancements within the field (Aria and Cuccurullo, 2017).

Although this approach has been utilized by Pritchard (1969), there are still limited bibliometric studies on livestock development (Rodriguez-Ledesma et al., 2015). Despite the growing interest in increasing CLA concentration in ruminant products, there is an intellectual disparity despite this topic being explored throughout the years (Acosta-Balcazar et al., 2024). Notably, there are no comprehensive bibliometric analyses have been conducted on CLA research in ruminant products. This study therefore aims to fill this gap by constructing a comprehensive scientific map to determine the trends and developmental shifts in research focused on enriched ruminant products, with a specific emphasis on CLA. This research will provide a thorough summary of this topic, offering valuable perspectives for researchers to address crucial research domains and advance the field.

MATERIALS AND METHODS

Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Moher et al., 2015; Khin and Rakthin, 2022) was employed to select eligible articles used in this study (Figure 1). This study focused exclusively on articles and reviews about CLA research in ruminant products published in academic journals between 2014-2024, deliberately excluding book chapters and

conference papers. Moreover, the selected articles were restricted to the fields of agricultural and biological sciences and required to be written in English. The articles were retrieved from the Scopus database using the Advanced Search function on 14 March 2024, with the search syntax specified in Table 1. Following this, the articles that met the criterion were exported in comma-separated value (CSV) file format containing complete entries (author information, title, institution, journals, abstract, keywords, funding details, and document type).

Subsequently, the retrieved data underwent comprehensive analysis using specialized software tools. Both *biblioshiny* from the *bibliometrix* package in R Software (Aria and Cuccurullo, 2017) and *VOSviewer* (van Eck and Waltman, 2010) were instrumental in analyzing the social networking of these articles and conceptual-intellectual structures using the author's keywords (Marino et al., 2023). Initially, the *biblioshiny* was utilized to conduct multifaceted analyses. This included determining Bradford's Law (Figure 3) and source growth (Figure 4), three-plot field (Figure 5), TreeMap for the author's keywords (Figure 6) as well as determining the thematic evolution of CLA research in ruminant products (Figure 8). The *biblioshiny* package was also employed to analyze relevant authors (Figure 9) on this specific topic. Additionally, *VOSviewer* was employed to investigate conceptual structures using the author's keywords (Figure 7) and social structures, specifically authors' and countries' collaboration networks within the articles (Figure 10). Furthermore, a meticulous process of eliminating duplicates, synonyms, plural and singular forms, and general terms not specific to the topic was employed to standardize the author's keywords. This approach ensured the accuracy and reliability of the data analysis.

Table 1 Search syntax in the Scopus database index

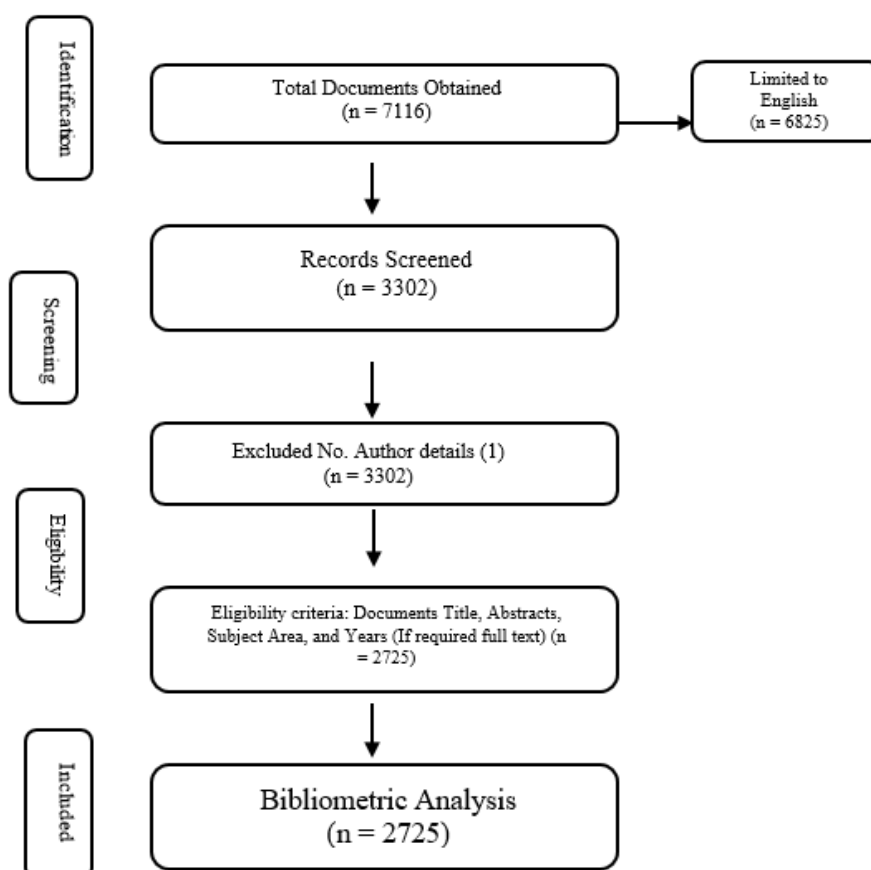| Data Source	Search Syntax
Scopus	("conjugated linoleic acid" OR "CLA" OR "CLA concentration") AND ("Animal Science") AND ("milk" OR "dairy") AND ("meat" OR "lamb" OR "beef" OR "ruminant products") AND PUBYEAR > 2014 AND PUBYEAR < 2024 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SUBJAREA , "AGRI")) AND (LIMIT-TO (DOCTYPE , "ar"))

Figure 1 The PRISMA methodology flowchart

RESULTS

Descriptive Analysis

The research literature concerning ruminant products published between 2014 and 2024 on CLA comprises 2,725 documents. However, there is a significant depression (-15.18%) in the annual growth rate of articles published (Table 2 and Figure 2). The prevalence of articles concerning CLA in ruminant products reached its peak in 2020, with 320 publications observed. The increase in publications occurred between 2014 and 2020, followed by a decline in subsequent years. The analysis of article sources identified 324 distinct journal titles (Table 2). Table 3 shows that the most frequent journals on the subject concentrated on animal production and animal science, with fewer focusing on agriculture and food science. Subsequently, core sources were examined using Bradford's law (Figure 3) (Bradford, 1985; Venable et al., 2014). The results displayed 33.797% of documents in the core sources, in which the *Journal of Dairy Science* published the most articles on this subject (9.064%), followed by *Animals* (7.963%), *Meat Science* (4.623%), *Animal Feed Science and Technology* (4.220%), *Small Ruminant Research* (4.147%), and the *Journal of Animal Science* (3.780%). Additionally, the *Journal of Dairy Science, Meat Science, Animal Feed Science and Technology,* and *Small Ruminant Research* are consistently leading sources for research on CLA in ruminant products, while *Animals* emerged as a primary reference in 2018 (Figure 4).

Table 2 Main information of CLA research documents retrieved from the Scopus database

Items	Data
Timespan	2014-2024
Sources	324
Documents	2725
Annual growth rate (%)	-15.18
Document average age	5.09
Average citations per doc	13.24
Keywords plus (id)	6691
Author's keywords (de)	5265
Authors	9979
Authors of single-authored docs	28
Co-Authors per Documents	6.39
International co-authorships (%)	29.39

Table 3 The 20 most frequent journals in the field of CLA research related to ruminant products

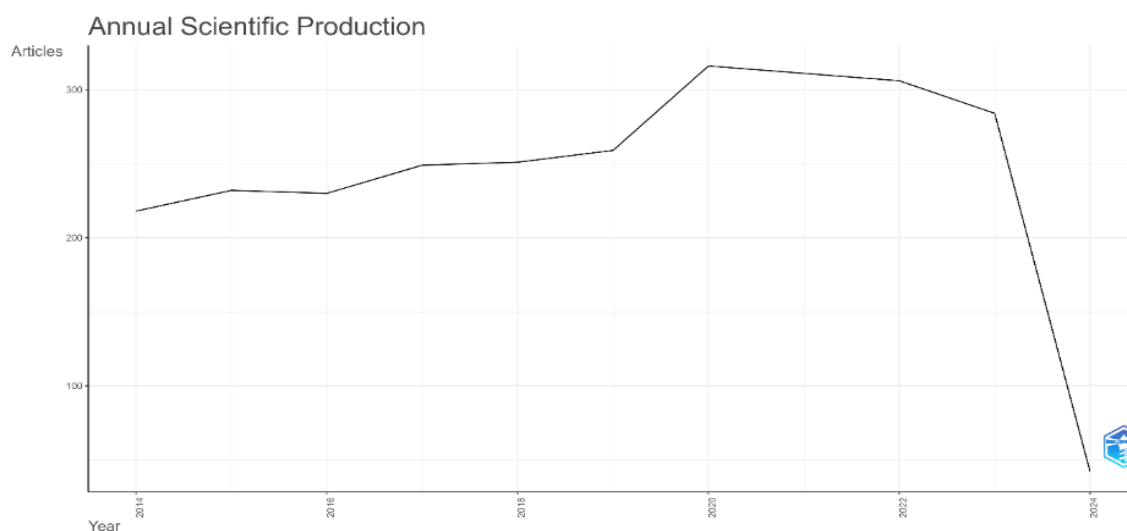| Sources	Articles	
	Amount	Percentage
Journal of Dairy Science	247	9.064
Animals	217	7.963
Meat Science	126	4.624
Animal Feed Science and Technology	115	4.220
Small Ruminant Research	113	4.147
Journal of Animal Science	103	3.780
Foods	78	2.862
Livestock Science	72	2.642
Animal	69	2.532
Animal Production Science	68	2.495
Italian Journal of Animal Science	62	2.275
Tropical Animal Health and Production	52	1.908
Journal Of Animal Physiology and Animal Nutrition	46	1.688
Canadian Journal of Animal Science	34	1.248
South African Journal of Animal Science	33	1.211
Asian-Australasian Journal of Animal Sciences	32	1.174
Annals of Animal Science	28	1.028
Journal of The Science of Food and Agriculture	28	1.028
Journal of Dairy Research	27	0.991

Figure 2 Number of CLA research articles on CLA in ruminant products published per year from 2014 to 2024 retrieved from the Scopus database
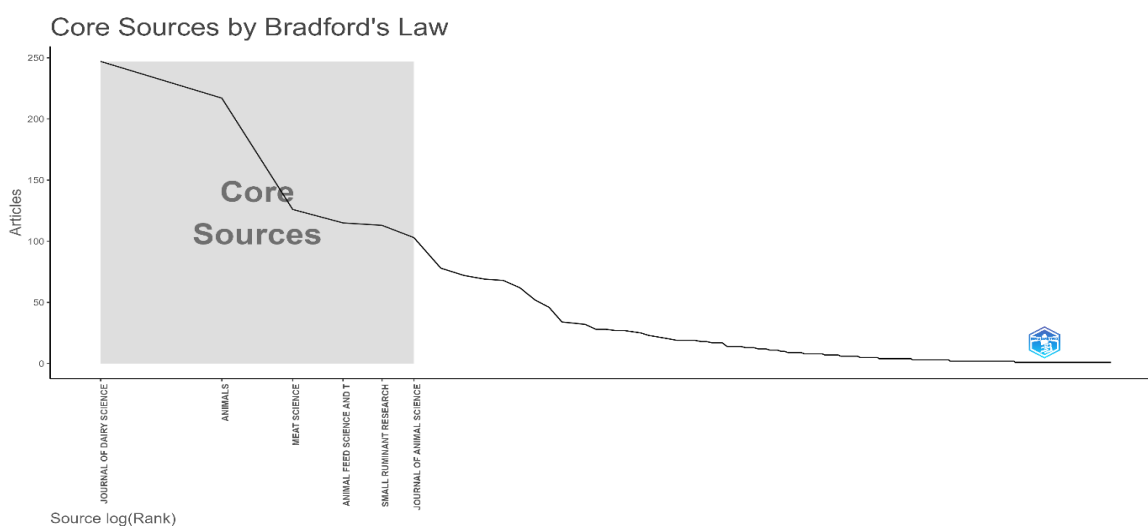

Figure 3 Bradford's law on core sources of research on CLA in ruminant products related articles
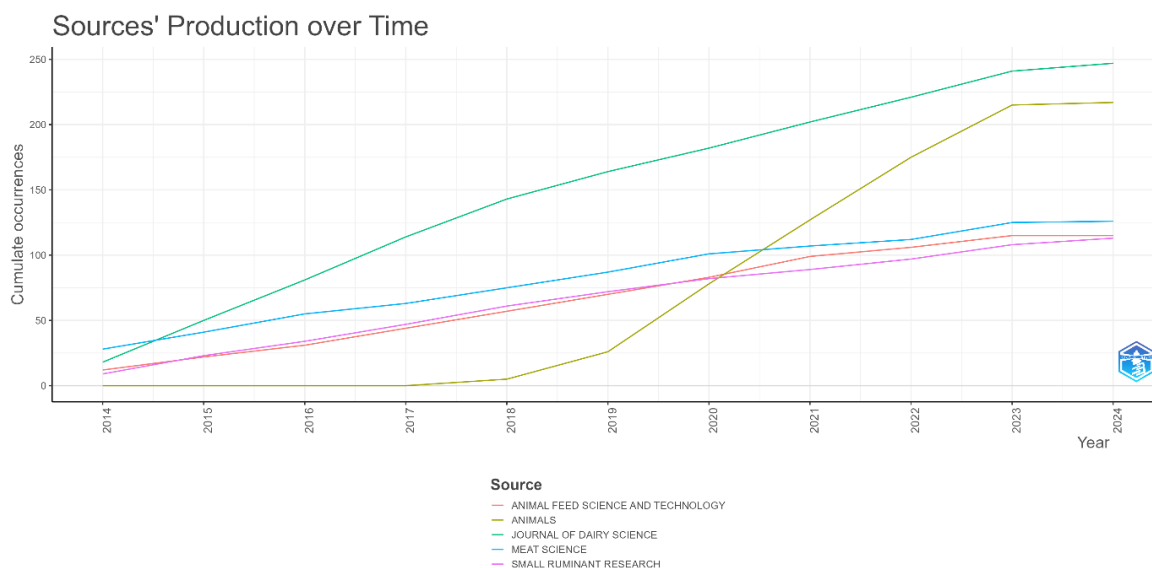
Figure 4 Source growth of research on CLA in ruminant products related articles

Intellectual and Conceptual Structures

The three-field plot for CLA research is presented in Figure 5, which visualizes the relationship among keywords, authors, and countries. This diagram shows the connection intensity among entities and directly correlates with the number of research conducted by each country and author regarding the subject matter. A total of 5,265 authors' keywords were used for articles on CLA in ruminant products, with "fatty acids", "meat quality", "CLA", "beef", "dairy cow", "sheep", "milk", "lambs", "growth", "biohydrogenation", and "milk yield" were predominant words used in the documents, as shown in Figure 6. Similarly, co-occurrence network analysis revealed "fatty acids," "conjugated linoleic acid," and "biohydrogenation" were predominant clusters in this subject (Figure 7). The evolution of the CLA research in ruminant products was characterized using thematic maps (Figure 8). The analysis of thematic evolution on this topic across two time periods highlighted basic themes, underscoring the significance of the subject matter, albeit indicating its limited development. Additionally, niche themes are substantial for CLA research in ruminant products, characterizing high density but low centrality, hence the topic has minimal impact on the area of study due to its strong internal connections but weak external connections.
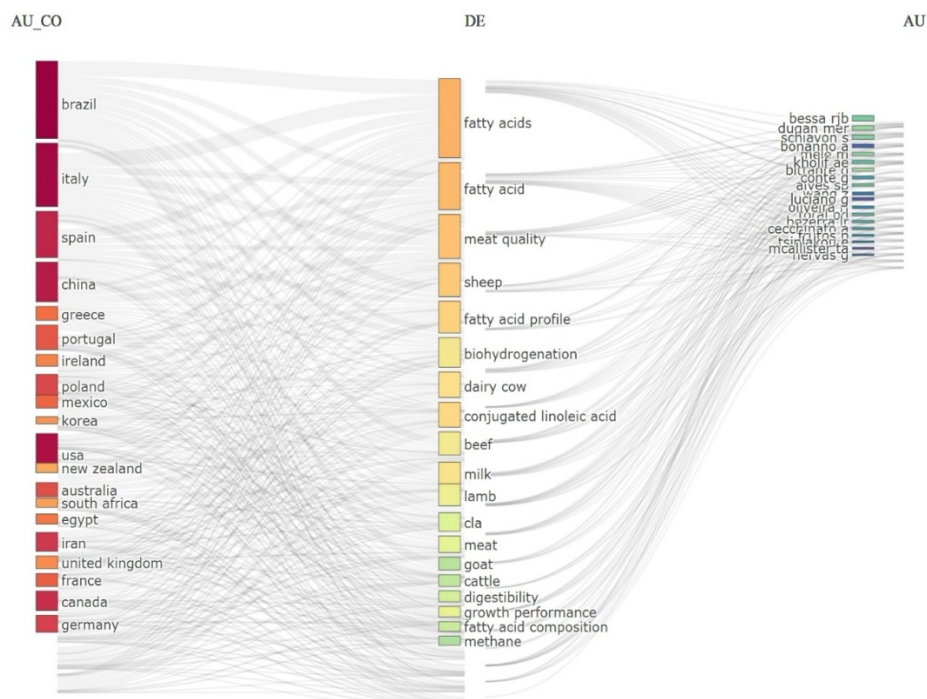
Figure 5 Three-plot field among countries (left), keywords (middle), and authors (right) on the research of CLA in ruminant products
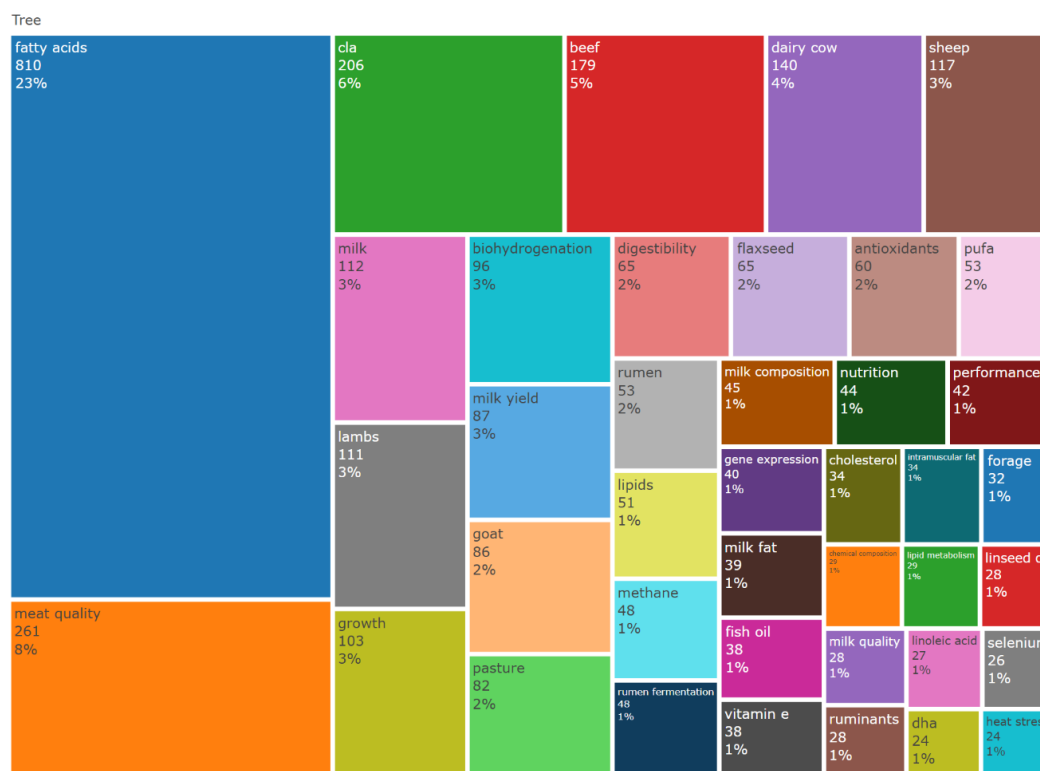

Figure 6 TreeMap on author's keywords used in research on CLA in ruminant products
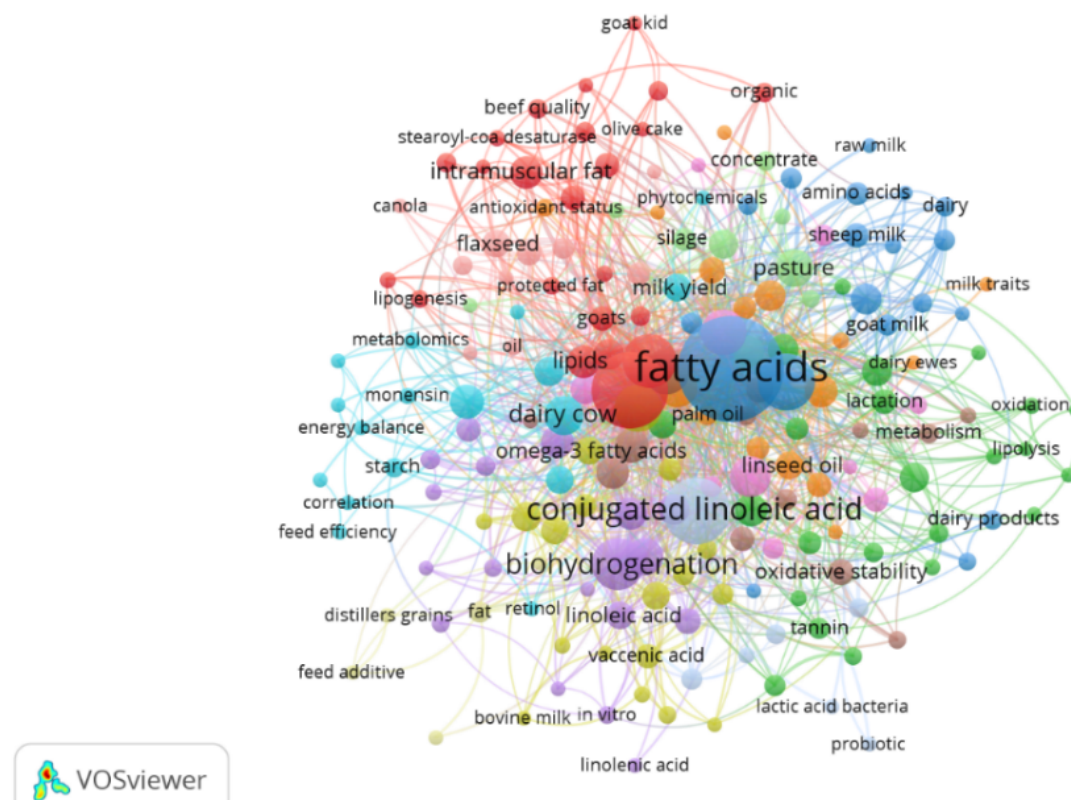
Figure 7 Co-occurrence analysis on keywords used in research on CLA in ruminant products. The author's keywords were organized into clusters, while the lines indicate the relationship strength. The area of each circle is proportional to the frequency of the corresponding author's keywords.

Social Structures: Authors and Collaboration Networks

A total of 9,979 authors contributed to articles on CLA research in ruminant products during 2014-2024 (Table 2). The average number of co-authors per document is 6.39, which indicates collaborative research efforts involving multiple authors are common within the research field. Most of the documents were published by multiple authors (99%), while merely 28 documents were produced by a single author. The top 30 most relevant authors are shown in Figure 9. This analysis was employed based on the fractionalized frequency of documents to account for the varying contribution levels of authors within multi-authored publications and highlight authors who have made substantial contributions, considering both quantity and quality. The United States of America (USA), Italy, and Brazil were the highest publishing countries in this subject during 2014-2024 (Figure 10), but these countries were not the most cited as shown in Table 4.

Figure 8 Thematic evolution of research on CLA in ruminant products created based on Bradford's Law for the periods 2014-2019 (A) and 2020-2024 (B). Density indicates the evolution of a topic, whereas centrality assesses the relevance level of a topic.

Table 4 Most cited countries in the field of CLA research related to ruminant products

Countries	Total Citations	Average Article Citations
Belgium	727	40.4
Romania	323	32.3
Netherlands	275	30.6
Israel	139	27.8
Ireland	940	23.5
Norway	116	23.2
Finland	182	22.8
Australia	1042	22.2
Spain	2912	19
Austria	37	18.5
Slovenia	35	17.5
Hungary	221	17
Morocco	33	16.5

Table 4 Cont.

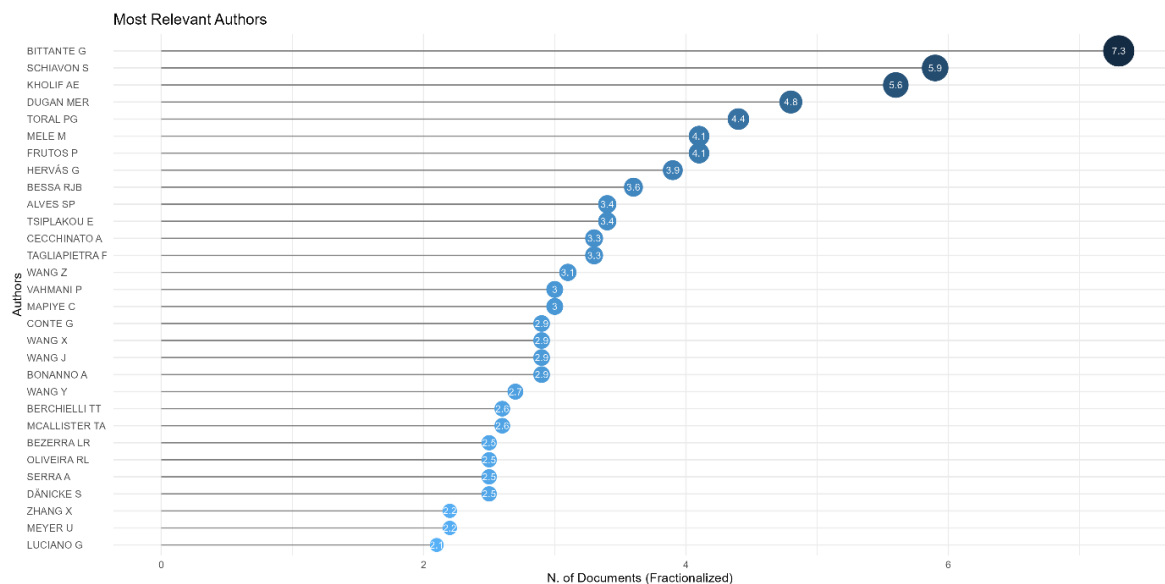| Countries	Total Citations	Average Article Citations
USA	3344	16.2
Ethiopia	63	15.8
Portugal	529	15.6
Tunisia	228	15.2
Egypt	724	15.1
Estonia	45	15
Italy	4101	14.8
Switzerland	236	14.8
Germany	835	14.4
Canada	994	14.2
South Africa	554	13.8
Malaysia	354	13.6

Figure 9 The most relevant authors for research on CLA in ruminant products
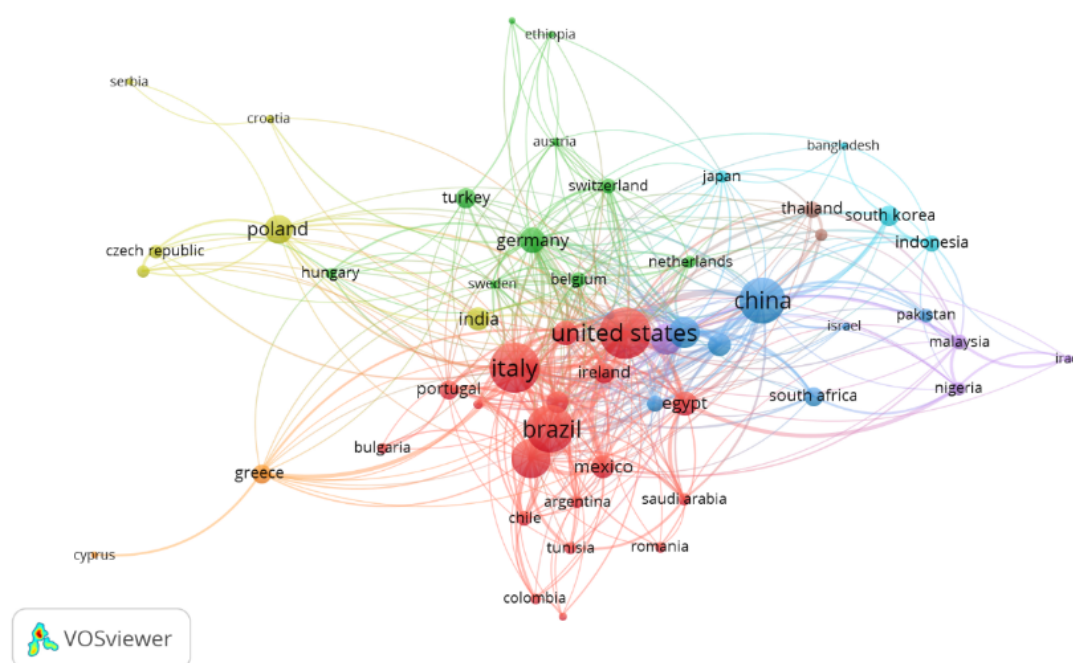
Figure 10 International research collaboration network for CLA in ruminant products

DISCUSSION

This study shows that there has been a decline in the annual growth of research on CLA in ruminant products over the period 2014-2024. Despite a growth in publications during 2014-2020, it declined in the latter years of the study period. Although the global crises could have resulted in a decline of publications (Larsen and von Ins, 2010), the research in this field was reaching its peak in 2020 at the outbreak of the COVID-19 pandemic. The declining annual growth of publications in the CLA field could potentially be due to the maturity and saturation of this subject as the area has been explored by Pariza and Hargraves (1985), in addition to resource limitations (Larsen and von Ins, 2010) and methodological improvements

Bradford's Law explains the reduced benefits as the search for references in journals extended exponentially. According to Bradford's Law (Bradford, 1985), there are six journals are included in the core sources (zone 1), which are the *Journal of Dairy Science, Animals, Meat Science, Animal Feed Science and Technology, Small Ruminant Research,* and the *Journal of Animal Science.* These journals in the core zone (zone 1) are characterized by citations in papers originating from a limited "core" selection of sources. Subsequently, zone 2 in Bradford's Law requires a larger number of journals to attain an equivalent number of citations, and the third zone necessitates even more journals, resulting in a decreasing number of references per journal through the transitions from zones 1 to zones 3 (Venable et al., 2014). The journals' sources of CLA research in ruminant products grew continuously during 2014-2024 (Figure 4) despite the depression in the annual growth rate of documents. This discrepancy could potentially be due to the saturation of the topics in the related field.

The three-field plot (Figure 5) depicts the relation among countries, keywords, and authors (Fatehi et al., 2020). Stronger connections indicate a higher level of research activity conducted by authors and countries. The larger

dimensions of the rectangle in the diagram relate to the number of studies carried out by authors or within countries and research domain (Fatehi et al., 2020; Ghassemi Nejad et al., 2023). Figure 5 shows that the primary interests in ruminant products research are "fatty acids", "meat quality", "sheep", "biohydrogenation", and "dairy cows" in all countries, conducted by authors in Brazil, Italy, Spain, and China. These results are similar to the TreeMap analysis generated in Figure 6 where "fatty acids" hold the largest proportion compared to other 5,265 author's keywords (22%). The word TreeMap visualizes the hierarchy based on the frequency of keywords (Schreck et al., 2006; Zou and Sun, 2021). Furthermore, Figure 6 shows fatty acids, CLA, meat quality, milk yield, milk composition, and gene expression were the analyses commonly used in evaluating ruminant product quality, such as beef, goat, lamb, and milk.

Additionally, the co-occurrence network analysis of the author's keywords examines the potential association between two bibliographic items found within the same articles (Zhou et al., 2022). Frequent co-occurrence implies thematic relationships among the keywords (Donthu et al., 2021). Similarly to the TreeMap and three-field plot, the co-occurrence analysis displays "fatty acids", "conjugated linoleic acids", and "biohydrogenation" as the center of the research landscape in ruminant products (Figure 7). Additionally, Figure 7 presents several feedstuffs (canola, distilled grains, flaxseed, olive cakes), feed additives (monensin), tannin, lactic acid bacteria, and probiotics. These materials are utilized in studies to increase CLA content and improve fatty acids in ruminant products (Maragkoudakis et al., 2010; Ladeira et al., 2014; Ragni et al., 2014; Santillo et al., 2016; Shivani et al., 2016; Chiofalo et al., 2020; Frutos et al., 2020). However, the small circle size of these keywords and positioned far from the central clusters in co-occurrence analysis implied they are not frequently explored by researchers in this field (van Eck and Waltman, 2010; Donthu et al., 2021).

The evolution of research in ruminant products is displayed in Figure 8. The thematic map is utilized to determine the relevance and development of themes in the field. The analysis was conducted in two periods, 2014-2019 (Figure 8A) and 2020-2024 (Figure 8B) to observe the advancements of this subject area. Both thematic maps showed that research in ruminant products was characterized by motor, basic, declining, or emerging, and niche themes. The basic topics are essential for the subject area but currently undeveloped. Niche themes have excellent internal connections, but weak external relationships. Motor topics are important due to being considered highly advanced and integrated themes (Marino et al., 2023). According to the analysis, the field was not characterized by motor topics during the first period. However, the basic themes, such as biohydrogenation, rumen fermentation, linoleic acid, microalgae, and sunflower oil, and niche themes, such as dairy cow, milk yield, milk fat, methane, and digestibility were transitioning to motor themes. In the second period, motor themes were present in the research on ruminant products. Among these topics are CLA, lipid profile, and polyphenols, which are the indicators of product quality and impacting market value. Other motor themes in the second period, such as pasture, soybean, vitamin E, and selenium, were considered as feedstuffs and feeding regimes utilized to modify CLA in ruminant products (Ianni et al., 2019; Rodríguez et al., 2020; Morittu et al., 2021). However, fish oil and linseed oil were regarded as niche themes, although these oils are rich in CLA precursors (Nudda et al., 2006; Luna et al., 2008; El-Nor and Khatab, 2012).

Eventually, the research in ruminant products focused on enhancing lipid profile, fatty acids, and CLA content according to the analysis. This has been achieved by utilizing various feeding management strategies, such as pasture or grazing which provide more forage to ruminants as this feedstuff is rich in α-linolenic acid, a precursor of CLA. Additionally, other feedstuffs rich in polyunsaturated fatty acids (PUFA), particularly linoleic acid such as sunflower oil, soybean, linseed oil, and fish oil, and feed additives, including monensin, probiotic,

and lactic acid bacteria have been supplemented to increase CLA content in ruminant products. These efforts aim to enhance the chemical and physical quality of ruminant products, transforming these materials into functional foods, and thereby enhancing their economic value.

CONCLUSIONS

The research on CLA in ruminant products has evolved significantly over the past decade. The analysis of the present study reveals a decline in the annual publication growth rate, potentially due to the saturation of the field and the need for new directions. Despite this decline, certain key journals continue to serve as core sources for CLA research in ruminant products. Moreover, the analysis highlights the prevalence of key topics such as fatty acids, meat quality, and biohydrogenation, indicating ongoing interest in these areas. However, certain emerging topics, including the utilization of several specific feedstuffs and additives, such as fish oil, linseed oil, probiotics, and lactic acid bacteria to enhance fatty acids and CLA content, have not been thoroughly investigated. Further research is required to explore these less studied topics and determine their potential contributions to the field. It is also essential to acknowledge that the present study is subject to certain limitations, including the database used and the varied methods and indicators utilized.

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AUTHOR CONTRIBUTIONS

Nursaadah Syahro Fitriyah: designing and concepting the study, collecting and analyzing the data, and writing the manuscript.

Lukman Abiola Oloudo : contributing to the critical reviews and editing of the manuscript.

Patipan Hnokaew: contributing to the critical reviews of the manuscript.

Siriporn Umsook: contributing to the critical reviews of the manuscript.

Tanakorn Tanukarn: contributing to the critical reviews of the manuscript.

Wiphawan Kueamanee: contributing to the critical reviews of the manuscript.

Prayad Thirawong: contributing to the critical reviews of the manuscript.

Trisadee Khamlor: contributing to the critical reviews of the manuscript.

Saowaluck Yammuen-Art: contributing to the critical reviews, editing of the manuscript, and funding the study.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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