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PROGRESS AND RESEARCH TRENDS IN LUMPY SKIN DISEASE BASED ON THE SCIENTOMETRIC ASSESSMENT – A REVIEW

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Abstract

Background: Lumpy skin disease (LSD) has been a significant concern in veterinary medicine since its discovery. Despite decades of research, understanding the full spectrum of this disease remains a challenge. To address this gap, a comprehensive analysis of the existing body of knowledge on LSD is essential. Bibliometric analysis offers a systematic approach towards the mapping of research landscape, identifying key contributors, and uncovering emerging trends in LSD research.

Objective: This study aims to conduct a thorough bibliometric analysis spanning from 1947 till the present date in order to map the knowledge domain of LSD. The objective is to gain insights into the global research trends, identify influential contributors, explore collaboration networks, and predict future outlook in LSD research.

Method: Data extracted from the Scopus database was used to perform a bibliometric analysis. 341 relevant documents were selected for analysis. Bibliometric indicators, including publication numbers, citation counts, and the h-index, were utilized to assess the comprehensive contributions of nations, organizations, authors, and source titles. Additionally, cooperation networks between countries, organizations, and authors were visualized using the VOSviewer tool.

Results: The analysis revealed a significant increase in research output on LSD, with a notable growth rate of 19.26%. Since its discovery in Zambia in 1929, LSD research has grown steadily, with an average annual growth rate of 5.21%. The University of Pretoria and the Federal Centre for Animal Health emerged as the most active institutions and organizations in LSD research. The Journal of Virology was identified as the most cited journal, reflecting its significant impact on the field, and a strong international collaboration was observed between the United Kingdom and South Africa.

Conclusion: This study provides valuable insights into the global research landscape of LSD, highlighting key trends, contributors, and collaboration networks. By reviewing decades of research, this analysis enhances our understanding of LSD and serves as a foundation for future research endeavors. The findings of this study will aid researchers in navigating the vast literature on LSD, ultimately contributing to advancements in veterinary medicine and disease management strategies.

Key words: skin disease, health, VOSviewer, virus, Scopus, database, data mining, bibliometric, animal, publications trends, animal

Capripoxvirus genus is classified as a member of the subfamily Chordopoxvirinae of the family Poxviridae (Bowden et al., 2008). The disease has spread from Africa to the Middle East, posing a severe threat to the large, domesticated members of the Bovidae family in Asia and Europe (Möller et al., 2019; Tufail et al., 2021). Furthermore, the illness seriously threatens the dairy and beef industries (Saltykov et al., 2021). According to the World Organization for Animal Health (WOAH) (Kumar et al., 2021), LSD was classified as a notifiable disease due to its potential for rapid spread and the potential to cause significant economic losses. The death rates in LSD vary from 50% to 100%, along with a high morbidity rate (Molla et al., 2017; Sudhakar et al., 2020). Furthermore, research indicates that the mortality rate is generally low (1–5%) (Casal et al., 2018). Acute and subclinical forms of the disease present different clinical pictures (Lojkić et al., 2018).

Meanwhile, the disease causes a significant reduction in milk yield (from 10% to 85%) due to high fever and secondary mastitis, resulting in severe economic losses in many countries (Möller et al., 2019; Saltykov et al., 2021). However, the sheep pox virus (ShPV) and the goat pox virus (GPV) are also members of the CaPV genus, which is also home to the lumpy skin disease virus (LSDV). These viruses are mechanically disseminated by stinging arthropods in contaminated environments

and skin abrasions (Alphonse et al., 2023; Roslidar et al., 2020). LSD has attracted much global research interest because it is an infectious disease. Specialists in infectious diseases are among the researchers who examine the illness from various scientific and clinical backgrounds. Additionally, several researchers published their data in highly regarded, peer-reviewed international journals, but no bibliometric analysis has been done to evaluate global publication trends for LSD studies over time. Furthermore, a sharp rise in the number of publications has been noticed, and systematic literature review studies are taking on a more active role in combining earlier research findings to effectively use the current data to develop a line of inquiry and provide evidence-based theory. In order to close the gap, this study uses articles from the Scopus database to provide a systematic review and bibliometric analysis of the hotspots, trends, and state of development in LSD research.

Numerous studies on LSD have been published globally, helping to identify gaps in knowledge and obtain important information about the current state of research. This study uses bibliometrics, a statistical analysis technique, to evaluate the characteristics of a specific research topic and significant trends in knowledge evolution (Hussain et al., 2021; Sajovic and Boh Podgornik, 2022). To obtain quantifiable, repeatable, and objective data regarding scientific activity in a specific field, bibliometric analysis is a valuable tool for learning about developments in that field. This statistical method is essential because of its multiple uses in various research domains and unique benefits. Numerous academic fields, such as the health sciences and engineering, have employed this scientific method to identify multiple patterns or trends (Fan et al., 2022). This study computed publication patterns (countries and journals), research hotspot tendencies (citation), growth rates for publications, and characteristics of research activities (keywords). The method provides insight into the growth, size, and distribution of scientific literature in the field of interest within a specified time frame (Ogunsakin et al., 2022). Thus, bibliometric studies, despite their methodological limitations, remain as valuable tools for assessing the scientific importance of a selected discipline (Fan et al., 2022). This tool analyses citation data (Fan et al., 2022; Klarasita et al., 2022), summarizes, visualizes, and characterizes a set or group of publications using publication patterns in the study areas through quantitative investigation and statistics. A field's historical, scientific research outputs can be studied to determine future research directions and collaborative opportunities, and the data or information derived from the visualizations or maps can be used for this purpose (Martín-Martín et al., 2021). The technique of bibliometric analysis, which describes publication patterns within a particular topic, is gaining popularity (Arici et al., 2019; Mulet-Forteza et al., 2019). The primary objective of this study is to identify the highly cited articles in LSD research, analyze their citation rate, and assess the number of authors per article. Additionally, it aims to evaluate the characteristics of the top contributing journals, recognize prolific authors, and delineate the most significant nations and features of the most cited papers. The study also aims to illustrate the publication life cycle of the most cited works in LSD research. Through bibliometric analysis, a study with a moderate level of detail can yield valuable insights, assisting researchers in defining the parameters of their investigation into a specific topic. Understanding the current state-of-the-art developments is facilitated by visualizing and uncovering the active knowledge structure for tracking the evolution of knowledge in LSD research.

The contributions of the current study are as follows:

- To evaluate the doubling time and annual relative growth rate (RGR) of research production in Lumpy Skin Disease (LSD) to determine past patterns of this activity.
- To find the most well-known authors and authorship trends in LSD research articles. In addition, a study measuring the degree of collaboration (DC) among LSD researchers will be conducted to determine the extent of collaboration within the scientific community.
- This study also examines how collaborative LSD research is distributed internationally among various nations.
- To find out the application of bibliometric analysis in LSD research.

Methods

For the systematic review of published articles on LSD, an extensive web search was conducted using the Scopus database (Mulet-Forteza et al., 2019).

Table 1. Requirements for inclusion and exclusion

Criteria	Inclusion	Exclusion	Justification
Subject	Lumpy skin disease	No exclusion	Included all LSD
Language	English	Other languages	Probabilities of misinterpretation of data in other languages
Access	Can access full text	Cannot access full text	To confirm the elucidation of an article more exactly
Method	All	No exclusions	All methods were included for a complete view
Article	Research and survey	Review, book, book chapter, conference paper, letter, data paper and editorial	Review articles understanding a comprehensive discussion over a subject would not adequately answer our research question accurately.

Selection procedure and eligibility standards

Two stages were involved in selecting the appropriate articles. Data extraction and categorization was done on the screened articles. To avoid prejudice, two researchers thoroughly reviewed and then examined the data independently. The first researcher carried out the screening of published studies from highly dependable indexed journals using keywords, titles, and abstracts. These articles were not restricted to case origin, citizenship, region, or nationality. The other researcher read full-length articles in detail and double-checked them one after the other in the second phase. Table 1 shows the requirements of this study based on inclusion and exclusion criteria.

Information source and search strategy

An extensive search of Scopus for bibliographic data on LSD was carried out utilizing the Boolean operators "OR" and "AND", and the search terms were entered into the "Article Title, Abstract, Keywords" field and combined. "Lumpy Skin Disease" OR "Lumpy Skin Virus" OR "LSV" OR "LSD" OR "Lumpy Skin Virus (LSV)" AND "Vaccines". The literature search was carried out to guard against any potential changes in citation and publication numbers fetched by database updates.

Data collection process

A search was done for title, abstract, and keywords to determine each article's eligibility and applicability for inclusion in this paper. The full articles were then subjected to a systematic analysis, and the outcome of this process guided the selection of articles. Four researchers worked independently to conduct data mining and analysis; a fifth researcher reviewed the data to ensure the validity. The downloaded bibliographic data is courtesy of Scopus and is available to the general public. The process of extracting this data did not cause any harm to human or animal subjects. Only English-language publications were included in this analysis, and the utilization of this data did not require ethics board approval or raise any ethical issue (Burnham, 2006; Pranckutė, 2021).

Data items, synthesis method, and certainty assessment

There are two types of bibliometric analysis methods: science mapping and performance analysis. An important and unique characteristic of bibliometric studies is the performance analysis, which prioritizes the effects of what constitutes a study and evaluates how scientists are cited in relation to scientific knowledge creation using several indicators. Separately, the links between various components of the research are the focus of bibliometric mapping and science mapping. Combining these two methods allows for evaluating bibliographical indicators with justification after developing various bibliometric analysis tools and software. Bibliometric data can be visualized through networks of keywords, co-citations, and collaborative relationships among authors, journals, institutions, and countries (Fan et al., 2022) and this study adhered to the five steps that guide quantitative and qualitative research for bibliometric analysis (Dervis, 2019; Klarasita et al., 2022). These steps include choosing the study region and duration, information source selection, search parameter creation, record identification (identification) and analyzing records as illustrated in Figure 1. Consequently, this study compared research published in journals using the same research standards across decades and countries. The dataset taken from the Scopus database for bibliometric indicators was processed and examined using the bibliometric R-package in R-studio v.4.1.1.

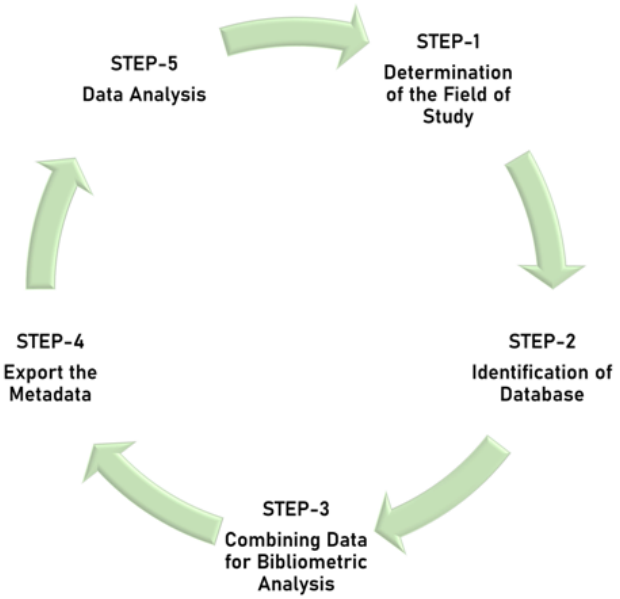

Figure 1. Schematic demonstration of the stages used for the bibliometric analysis. Each stage illustrates the flow and methodology of the bibliometric analysis

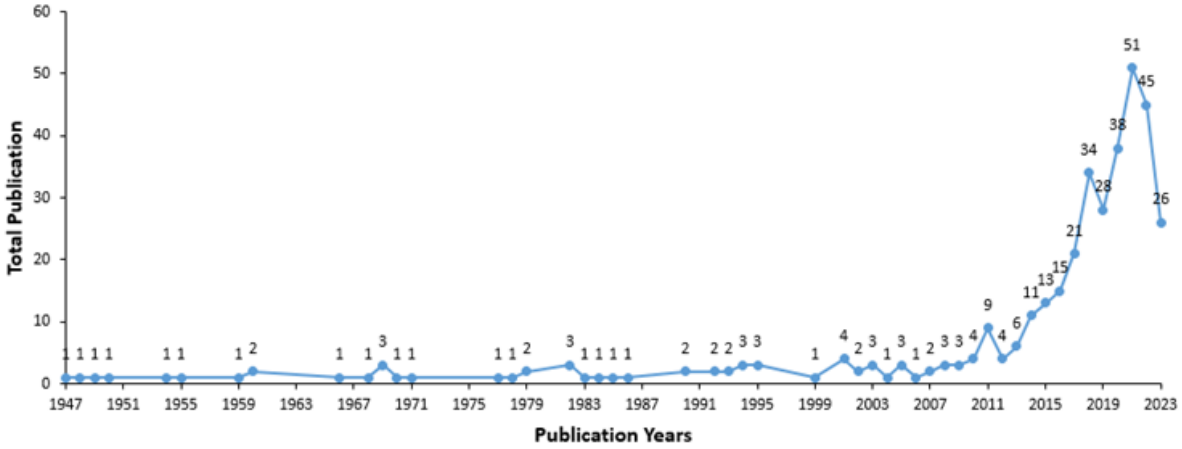

Figure 2. Spatial distribution of the bibliographic documents per year (excluding years with no publication). It showed the year-wise publication trends of LSD research

The bibliometrics R package contains a fundamental analytical algorithm for statistics and science mapping. It was employed to visualize the number of yearly publications, citations, authors, institutions and countries of journal sources in Scopus after they were retrieved and summarized. *Biblioshiny*, a web interface program, is included in more recent versions of the bibliometrics R-package to assist users in performing bibliometric analysis without any programming experience. Furthermore, by analyzing the frequency with which the precise keywords appeared in the documents, *VOSviewer* established a cluster with different nodes on a map which can represent other elements, such as a nation, organization, or set of keywords. The size of the nodes indicates the quantity or frequency of publications, authors, or keywords; the more significant the node, the greater the frequency or number of publications. The degree of co-occurrences or collaborations is indicated by the thickness of the lines that link two nodes. A different color of nodes and lines represents each cluster (Fan et al., 2022).

The growth rate of publications over time was obtained by raising the rate of publications in 2022 divided by the number of publications in 1947 to the power of 1/75, subtracting one from the result and multiplying it by. The growth rate is calculated using the below equ. (1):

$$\lambda = \left((\alpha \div \beta)\right)^{1/75} - 1 \times 100 \quad (1)$$

The annual growth rate (AGR) was calculated, which was determined by calculating the percentage change in the annual publication count. In terms of mathematics, it is represented in below equ. (2):

$$\eta = [(\pi_2 - \pi_1)/\pi_1] \times 100 \quad (2)$$

Results

General trend about publications time distribution

Figure 2 estimates the annual trends and changes in the publishing of LSD research. Publications began in 1959 and remained consistently at one publication each year, with sporadic peaks and minor variations during the 1960s and 1990s. The 2000s saw a significant increase in growth, beginning with four publications in 2001. There was a noticeable uptick in the trend in 2014 (11 publications), 2015 (13 publications), and 2016 (15 publications). With 21 publications in 2017, 34 in 2018, 28 in 2019, and 38 in 2020, there was a noticeable upsurge starting in 2017. The number of publications peaked in 2021 at 51 and continued to rise steadily in subsequent years, with 45 publications in 2022 and 26 in 2023.

Publication trends among countries

Published articles from different nations show the influence respective nations have on LSD. Table 2 displays the research output about LSD for the top 10 countries with the most activity. The countries with the highest article publications are Egypt, South Africa, and the United Kingdom, and this result suggests that developed nations publish more LSD research. Table 2 shows that South Africa accounted for the largest percentage of publications (35/341, 10.26%), followed by the United Kingdom (17/341, 9.97%), Ethiopia (13/341, 3.81%), and Israel (12/341, 3.52%).

Impact of the most local citations and sources

In Table 3, the top 20 sources are ranked based on local citations and regional impact using the h-index to evaluate the sources. The h-index, also known as the "high citations" or "h-factor," serves as a valuable metric for assessing scholarly articles within academia (Wang

et al., 2009). The evaluation revealed that other highly referenced sources include PLOS One (88), Veterinary Record (86), Journal of Virology (82), Journal of Virological Methods (80), and Preventive Veterinary Medicine. With regards to the impact of local sources and the quantity of locally cited sources (h-index = 1, m index = 0.05, and total citations (TC) = 59, respectively), the Journal received grades of 24 and 17, respectively, with 344 and 292 TCs and 8 and 6 h-indices. One of the top 20 journals with the most significant local impact was Archives of Virology, published by Springer Media SA, which has an h-index of 8 and a TC of 243. Utilizing the analyzed dataset, the Journal was placed eleventh with an h-index of five.

Most cited documents

The top 20 most frequently selected articles that are globally cited (GC) and locally cited (LC) are listed in Tables 4 and Table 5. The "local citation" of an article refers to the total number of citations it garners from articles within the analysis data that are specifically dedicated to the subject of the review. Remarkably, an article's impact on LSD research rises with LC and falls with GC. The number of citations is one way to measure an article's impact and visibility in the research community, but it can also be a better indicator of the article's quality. From Table 4, the publication by Tulman et al. (2001) has a cumulative TC of 182 and an annual total citation count of 8.27. It has garnered the highest number of citations worldwide. The article authored by Chihota et al. (2001) and published in the Journal of Virology in 2001 received 165 citations, ranking it second on the list of most globally cited articles and the third-ranked publication on the list was authored by Tuppurainen et al. (2005) and published in the Journal of Veterinary Research. The first LSD case reported in the European Union impacted two beef livestock holdings in Greece (Union and Health, 2015) and on August 21, 2019, the World Organization for Animal Health (WOAH, formerly OIE) received reports of cases in the Greek province of Evros, near the border between Turkey and Europe.

Based on local citation data, the studies by Babiuk, Tuppurainen, Carn, Tulman, Hunter, Tasioudi, Gari, Prozesky, Tageldin, and Yeruham were ranked amongst the top 20 globally and locally referenced publications. Looking at local citations, it was surprising that the article published by Chihota et al. came in first with 165 worldwide citations and 94 local citations. The local article authored by Babiuk et al. (2008) received the second-highest mentions, while Tuppurainen's publication came in third. Remarkably, Chihota received more regional than international citations for her published work.

Table 2. Productivity of top 10 contributing countries based on the number of articles

Rank	Countries	Papers in country category (N = 341)	SCP	MCP	MCP Ratio
1	South Africa	35 (10.26)	20	15	0.429
2	Egypt	34 (9.97)	30	4	0.118
3	United Kingdom	17 (4.99)	7	10	0.588
4	Ethiopia	13 (3.81)	7	6	0.462
5	Israel	12 (3.52)	8	4	0.333
6	Belgium	11 (3.23)	3	8	0.727
7	China	10 (2.93)	10	0	0.000
8	Turkey	10 (2.93)	9	1	0.100
9	Germany	9 (2.64)	3	6	0.667
10	Iran	9 (2.64)	9	0	0.000

Table 3. 20 local sources that have the biggest local influence

Journal	Most significant local source impact				Maximum local citation documents	
	h_index	g_index	m_index	TC		
1	2	3	4	5	6	
Transboundary and Emerging Diseases	19	31	1.267	1091	Transboundary and Emerging Diseases	399
Archives of Virology	8	11	0.286	243	Vaccine	242
BMC Veterinary Research	8	9	1.000	136	Virology	133
Preventive Veterinary Medicine	8	10	0.667	172	Epidemiology and Infection	114
Vaccine	8	8	0.267	344	PLOS One	88
Journal of Virological Methods	7	9	0.438	173	Veterinary Record	86
Onderstepoort Journal of Veterinary Research	6	8	0.105	292	Journal of Virology	82
Tropical Animal Health and Production	6	11	0.162	158	Journal of Virological Methods	80

Table 3 – contd.

1	2	3	4	5	6	
EFSA Journal	5	6	0.625	142	Preventive Veterinary Medicine	72
Epidemiology and Infection	5	5	0.179	392	Tropical Animal Health and Production	72
PloS One	5	7	1.000	117	Preventive Veterinary Medicine	72
Veterinary Microbiology	5	6	0.333	115	Onderstepoort Journal of Veterinary Research	71
Veterinary World	5	7	0.417	139	Archives of Virology	69
Frontiers in Veterinary Science	4	5	0.571	83	EFSA Journal	67
Genome Announcements	4	4	0.571	89	Veterinary Microbiology	62
Microbiology Resource Announcements	4	5	1.000	35	Research In Veterinary Science	61
Vaccines	4	6	1.333	40	Theriogenology	58
Antiviral Research	3	3	0.300	136	Medical and Veterinary Entomology	52
The Veterinary Record	3	3	0.091	157	BMC Veterinary Research	39
Ticks and Tick-Borne Diseases	3	3	0.300	98	Genome Announcements	38

Table 4. Top 20 papers cited worldwide

Reference	TC	TC per year	Normalized TC
Tulman et al., 2001	182	8.27	1.65
Chihota et al., 2001	165	7.50	1.49
Tuppurainen et al., 2005	119	6.61	1.67
Babiuk et al., 2008	114	7.60	1.80
Carn and Kitching, 1995	99	3.54	1.23
Yeruham et al., 1995	90	3.21	1.12
Hunter and Wallace, 2001	82	3.73	0.74
Romero et al., 1993	78	2.60	1.70
Chihota et al., 2003	77	3.85	1.52
Wallace and Viljoen, 2002	77	2.66	1.93
Tuppurainen et al., 2011	76	6.33	2.17
Tuppurainen et al., 2014	73	8.11	2.33
Tasioudi et al., 2016	72	10.29	2.87
Tuppurainen et al., 2013	69	6.90	1.76
Ben-Gera et al., 2015	65	8.13	2.08
Kara et al., 2003	63	3.15	1.24
House et al., 1990	62	1.88	1.02
Tageldin et al., 2014	59	6.56	1.49
Irons et al., 2005	59	3.28	0.98
Magori-Cohen et al., 2012	58	5.27	1.89

Table 5. List of the twenty most frequently cited local documents

Reference	LC	GC	LC/GC Ratio (%)
Chihota et al., 2001	94	165	56.97
Babiuk et al., 2008	85	114	74.56
Tuppurainen et al., 2005	80	119	67.23
Carn and Kitching, 1995	71	99	71.72
Tulman et al., 2001a	65	182	35.71
Hunter and Wallace, 2001	58	82	70.73
Tasioudi et al., 2016	55	72	76.39
Tuppurainen et al., 2011	50	76	65.79
Chihota et al., 2003	50	77	64.94
Tageldin et al., 2014	43	59	72.88
Yeruham et al., 1995	43	90	47.78
Tuppurainen et al., 2013	41	69	59.42
Gari et al., 2010	41	51	80.39
Magori-Cohen et al., 2012	40	58	68.97
Irons et al., 2005	39	59	66.10
Sprygin et al., 2018	37	47	78.72
Brenner et al., 2009	37	58	63.79
Carn and Kitching, 1995	36	52	69.23
Kara et al., 2003	34	63	53.97
Salib and Osman, 2011	33	56	58.93

Most popular keywords included in a word cloud

The results of the word cloud analysis utilizing the authors' keywords are shown in Figure 3. The findings show which diseases are most common and which areas have had more outbreaks occurring. The term "lumpy skin disease virus" appears 53 times, whereas "lumpy skin disease" appears 109 times. Other noteworthy terms are "capripoxvirus" (32) and "vaccine" (35), as well as "cattle" (36). PCR methods, phylogenetic analysis, immunization, epidemiology, and disease control are necessary to study fields that dominate the world.

Figure 3. Word Cloud for author keywords. This word cloud is generated from the author keywords used in the collected bibliographic documents. The size of each word in the cloud reflects its frequency of occurrence. This visual representation highlights the most common themes and topics of interest among the authors in the dataset and primary areas of focus within the LSD research

Co-occurrence network analysis using keywords and keywords plus

For the lumpy skin disease condition study, the keyword-co-occurrences links are shown in Figure 4. Two types of co-occurrences of authors' keywords exist. The number of nodes in the network of keyword co-occurrences, which measures the author-keyword co-occurrence ranking, represents the frequency with which two keywords occur together, and the significance of the terms increases with node size. The colors of the nodes indicate other clusters, and how the nodes appear where the keywords are found. The nodes' links explain the associations and relationships (Heyat et al., 2024; Zeeshan et al., 2023).

The authors' keyword selections and keyword-plus distribution were also assessed to determine the most popular search terms and user preferences. The advancement of science has been greatly aided by examining the writers' keyword usage, which shows research trends (Ma et al., 2022; Ogunsakin et al., 2022). Keywords Plus provides additional search terms derived from the titles of the article's authors cited in their bibliographies and footnotes. Co-occurrence-network analysis has been used to look for trends and study LSD. Additionally, co-occurrence-network analysis was utilized to discover more about the trends in LSD research. In contrast, cluster analysis could be employed to examine the themes that emerge from the authors' keywords and keyword variations in the articles.

Author keyword distribution

The author keywords from LSD studies were examined, and 588 keywords were identified. After examining the author keywords in LSD-related papers, the top 50 keywords were chosen and arranged chronologically (Figure 5). The general illness and diagnostic elements are shown with the blue cluster, and the terms that are being looked at include "lumpy skin disease," "sheep pox virus," "parvoviridae," "vector," and "diagnosis." Understanding the illness, locating its vectors, and diagnosing infections are the main foci of this cluster. The red cluster focused on cutting-edge sequencing and diagnostic methods, and prominent terms in this cluster include "nanopore sequencing," "sppv" (sheep pox virus), "sheep pox," "Capri pox," "LSDV" (lumpy skin disease virus), "inactivated vaccine," "ELISA" (enzyme-linked immunosorbent assay), and "real-time PCR." This cluster dealt with the development of vaccines, virus identification, and molecular diagnostics. Keywords that formed the green cluster mainly considered genetic and molecular aspects of LSD. Terms that fell under this cluster include "p32 gene," "GPCR" (G-protein-coupled receptor), "lumpy skin disease virus," "PCR" (polymerase chain reaction), and "sheep pox virus". These keywords came from publications that looked at molecular characterization and genetic study of the virus. Co-infections and other important cattle diseases are keywords associated with the yellow cluster. Phrases like "peste des petits ruminants," "sheep pox," and "Rift Valley fever" point to the larger picture of animal health and the effects of various illnesses on cattle. Finally, the pink cluster is centered on theoretical and preventive strategies. "Vaccine" and "mathematical model" are among the keywords that characterize this group of researchers.

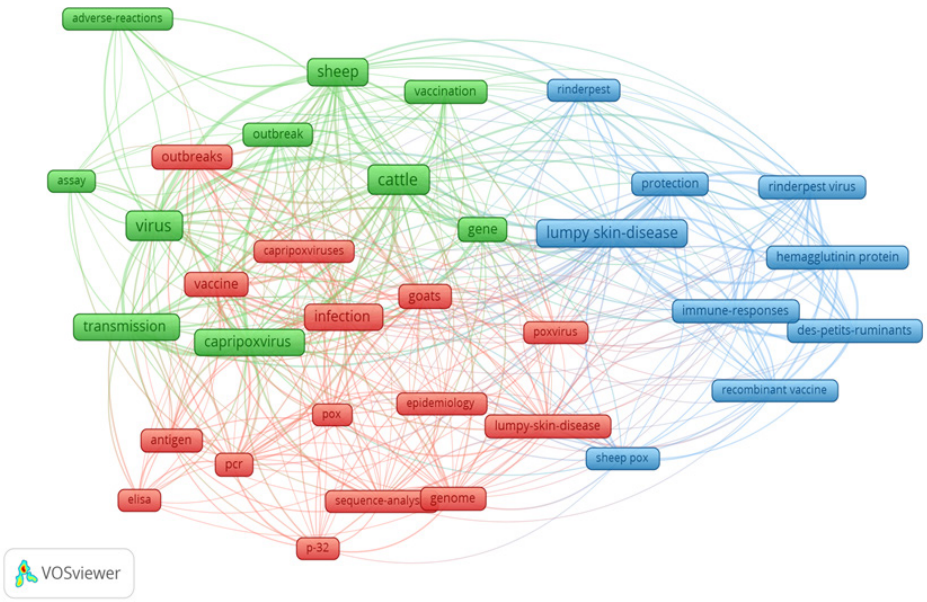

Figure 4. Keyword-co-occurrence-network visualization**.** It illustrates the relationships between keywords based on their co-occurrence in the LSD bibliographic documents. Nodes represent individual keywords, while the connecting lines (edges) indicate instances where two keywords appear together in the same document

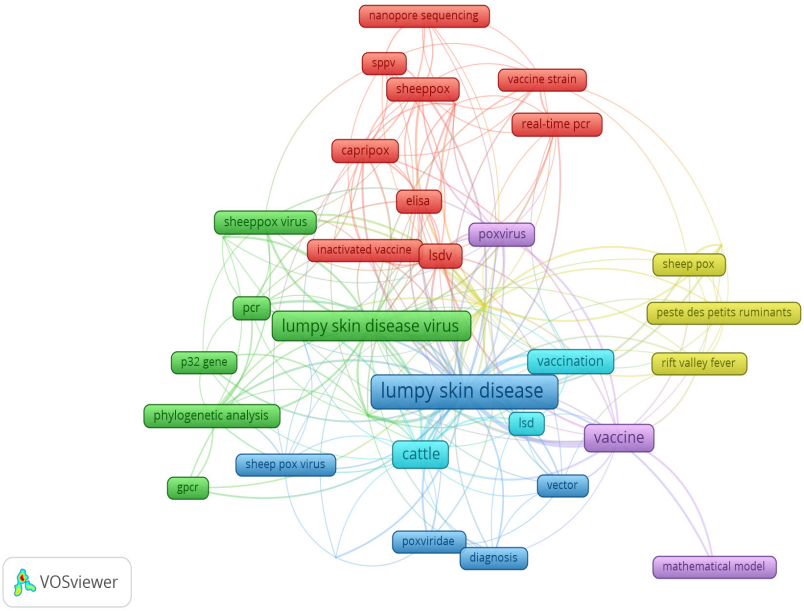

Figure 5. Top 50 author terms in papers about LSD**.** This visualization provides a clear overview of the primary topics and focus areas in the literature related to LSD

Previously confined to Africa, LSD has been the cause of several significant pandemics, posing threats to food security and exacerbating poverty (Saegerman et al., 2019; Sprygin et al., 2019), with arthropods being the most natural vectors of the disease (Tuppurainen et al., 2015). Due to the migration of these arthropod species that acted as carriers, LSD spread across countries or continents (Sprygin et al., 2019). PCR, LSDV, outbreak, LSD, and cattle, which were among the terms associated with the spread of LSDV, are found in the second cluster. Principal cells originating from caprine, ovine, and bovine sources are commonly employed for LSDV isolation (Babiuk et al., 2007; Binepal et al., 2001; House et al., 1990; Salnikov et al., 2018). It is believed that the primary bovine dermis and primary lamb testicle (PLT) cells are the most susceptible to LSDV (Tuppurainen et al., 2020). Primary goat kidney (PGK) cells revealed cytopathic effect (CPE) during the first passage. PGT cells did not show CPE until the fourth unseen passage, whereas PLT cells revealed CPE during the third blind passage. The PGK cell line is noted for its heightened susceptibility to LSDV isolation among the three primary cell lines employed. However, the creation expenses, inefficiency, and vulnerability to infection render primary cells incompatible with contemporary initiatives aimed at minimizing animal use in research. Madin-Darby bovine kidney (MDBK) cells have been widely used to propagate high titers of LSDV in vitro (Binepal et al., 2001; Fay et al., 2020; Salnikov et al., 2018). Several studies have referred to MDBK cells for LSDV isolation. However, these cells' sensitivity compared to PGK cells for LSDV isolation is still under investigation. It is also worth noting that recent data suggest that LSDV transmission is accomplished via the MDBK cell line (Fay et al., 2020; Möller et al., 2019; Munyanduki et al., 2020; Wallace and Viljoen, 2002).

The development of a focus formation test for LSDV in MDBK cells presents a challenge due to the difficulty in accurately counting foci under a microscope. While MDBK cells are susceptible to LSDV during *in vitro* propagation, just like other cell types, the virus does not result in plaques in MDBK cells. LSDV could be modified in Vero cells for the first time if the LSDV develops plaques in a different cell line. After LSDV (isolated in PGK cells) was directly injected into Vero cells, no CPE was observed. CPE was later observed in the fourth passage (P4), indicated by cell clustering (foci), which is similar to those previously observed in the MDBK cell.

"Hematology" and "biochemistry" were included in the third cluster. "Genome," "virus," "recombination," and "real-time PCR" were present in the fourth cluster. The fifth cluster included terms such as "LSD," "risk factors," "Ethiopia," "prevalence," and "seroprevalence." The first reports of LSD outbreaks were from Northeast Vietnam, and the RP030 and p32 sequences were found to be 100% identical to those from China. This lends credence to the possibility that the disease entered Vietnam from China through the border. According to recent studies, the LSD virus strains from China and Xinjiang in 2019 were grouped into a different cluster from the LSD virus from Russia (Lu et al., 2021).

Bibliometric analysis of academic alliance

Figure 6 shows academic collaboration between researchers. According to the research by Ogunsakin

et al. (2022), collaboration between researchers usually promotes knowledge and communication, broadening the study area. The bibliophile interface was used to visualize the cooperative network and the authors' cooperation in scientific research is shown in the author-collaboration map. Meaningful collaboration connections occurred on multiple levels, as expected in LSDV research. The authors were ranked based on the total number of citations to determine who contributed the most. The blue cluster comprises researchers such as G. Gari, C.M. Chihota, and J.A. Woods, who have significantly contributed to various areas of LSD research, potentially addressing local outbreaks or vaccine development. In the red cluster, researchers such as E.S.M. Tuppurainen and J. Hamdi, are prominently featured, showcasing their extensive involvement in studying the virus's molecular biology, epidemiology, and defense mechanisms. Researchers who worked on genetic studies or cutting-edge diagnostic procedures include J. Wolff and A. Sprygin, among others, in this category. The green cluster consists of reputable specialists with a solid background in LSD research, such as F.G. Davies, and J.A. Coetzer. Researchers specializing in the virology and pathophysiology of the LSD, such as T.R. Bowden and E.R. Tulman, play significant roles in advancing our fundamental understanding and historical knowledge of the virus.

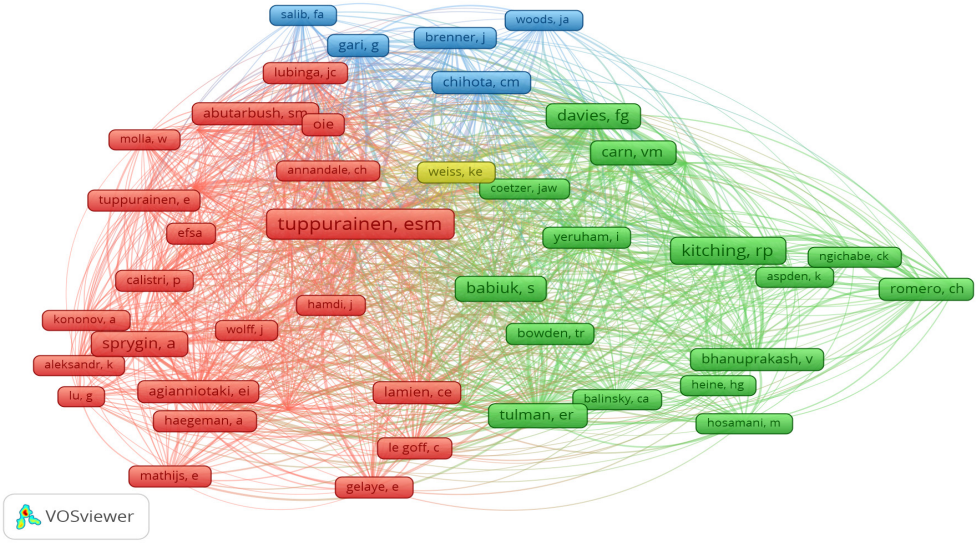

Figure 6. Bibliometric visualization of the academic alliance. The visualization maps out the collaborative relationships between different authors working on LSD. Nodes in the network represent individual authors, while edges indicate collaborative links between them

Table 6. Nations which have the highest average number of citations per article and total number of citations

Country	TC	Average article citations
South Africa	792	22.63
United Kingdom	783	46.06
Israel	371	30.92
Egypt	343	10.09
Ethiopia	337	25.92
USA	256	51.20
Greece	177	29.50
Belgium	156	14.18
Jordan	134	26.80
Canada	132	66.00
Oman	114	38.00
Italy	97	19.40
Germany	94	10.44
Turkey	92	9.20
Kenya	79	19.75
Serbia	59	19.67
Iran	54	6.00
Netherlands	52	13.00
China	50	5.00
France	45	45.00

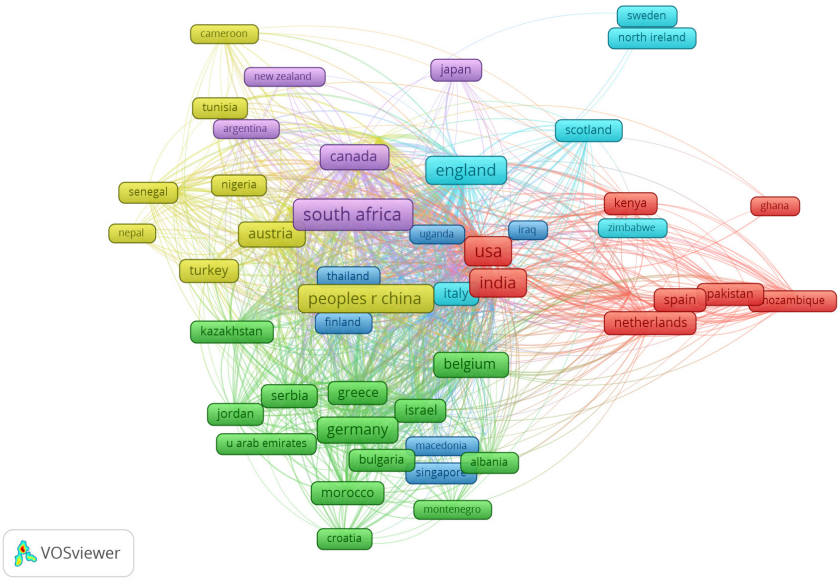

Figure 7. Visualization of the cooperative network by the nation. Each node represents a country, and the connecting lines (edges) between nodes indicate collaborative ties between those countries. This visualization offers insights into global research networks in LSD research

Countries with the most cited collaborations

The nations with the most citations, total citation counts, and average citations per article are presented in Table 6. The data presented in this table indicates that South Africa, United Kingdom, Israel, and Egypt had the highest average number of article citations, at 22.63, 46.06, 30.92, and 10.09, respectively. Considering the significance of collaboration, assessing the degree of cooperation through inter-institutional partnerships is advantageous.

As illustrated in Figure 7, the community collaboration network of LSD-related articles facilitates the exchange of ideas among leading countries in this field. The network's four distinct colors denote an increasing diversity in research trends. The critical nodes represent the top nations, while the connections between the nodes demonstrate the formation of strong bonds. The breadth of the relationships and the distance between nodes also provide insight into the level of national cooperation. The strength of the partnerships determines the proximity of ties between the nations. This collaborative network demonstrates significant connections with South Africa, Zambia, Australia, and Kazakhstan, encompassing collaborations with nations in Africa, Europe, and neighboring regions. South Africa spearheads a second group, closely collaborating with Kazakhstan, Canada, and France, furthermore serving as a pivotal hub for global cooperation within the network.

Most important institutional partnerships and affiliations

The assessment of the cooperation and input from different institutions was primarily centered on the affiliations of the institutes and the documents authored by at least one of them. The data identified the top 20 institutions with more than 20 papers. As illustrated in Table 7, the Federal Centre for Animal Health in Vladimir Oblast, Russia, had the most substantial influence on the LSDV study. Following closely behind, the University of Pretoria produced 80 articles, trailed by the University of Cape Town with 43 articles, The Pirbright Institute with 59 articles, and Sciensano with 48 articles. The entity that ranked first contributed 122 articles related to LSD. Based on excellent publications, the Research Institute for Biological Safety Problems is a reputable research organization.

Table 7. Highest quantity of articles and most pertinent affiliation

Affiliation	Articles
Federal Center for Animal Health	122
University of Pretoria	80
The Pirbright Institute	59
Sciensano	48
University of Cape Town	43
Kimron Veterinary Institute	39
Animal Health Research Institute	29
Aristotle University of Thessaloniki	29
Department of Nuclear Sciences and Applications	25
Institute of Diagnostic Virology	24
Athens Veterinary Center	22
Onderstepoort Veterinary Institute	22
Federal Agency of Scientific Organizations	21
Zagazig University	20
Institute for Animal Health	19
National Institute of Veterinary Research	19
Research Institute for Biological Safety Problems	19
South China Agricultural University	19
Federal Research Center for Virology and Microbiology	17
Beni Suef University	16

The analysis identified eight clusters in the institution-collaboration pattern among the top 50 most productive institutions/organizations. The two primary groups were the National Institute of Veterinary Research and the University of Pretoria. Gilead Science, a biopharmaceutical company, played a significant role in facilitating cooperation between these establishments. The National Centre for Animal Health and the Federal Centre for Animal Health at Vladimir Oblast emerged as the two main subgroups within these groups. In fostering collaboration among different organizations, the research-oriented Research Institute of Biological Safety Problems served as a connecting link.

Discussion

The results obtained from this bibliometric analysis of LSD research have revealed significant and groundbreaking insights. This paper offers a comprehensive examination of the productivity and trends in LSD research, representing a novel and in-depth analysis. This study represents the first comprehensive analysis of 75 years of LSD research. The findings reveal a growing trend in published articles and documented outbreaks. The apparent increase in LSD research publications may be attributed to advancements in technology and their impact on scientific exploration. LSD has become a problem for Asian livestock managers (Namazi and Khodakaram Tafti, 2021; Tuppurainen et al., 2018). This observation is substantiated by prior research indicating that the number of publications issued over time could be a dependable indicator of productivity (Bornmann and Mutz, 2015; Garg and Rao, 1988). This analysis reveals that 341 documents, constituting approximately 89% of all published documents, were sourced from the Scopus database. The majority of the journals that ranked top for the most significant number of locally cited sources were Transboundary and Emerging Diseases (n = 399 articles), Vaccine (n = 242 articles), and Virology (n = 133). In comparison, the impact factor literature contained the most cited papers on LSD research; the total number of citations ranged from 58 to 182. Tulman et al. (2001) paper from Journal of Virology, with 182 total citations, and Chihota et al. (2001) paper from Epidemiology Infection, with 165 total citations, were the most cited LSD documents on Scopus.

Furthermore, distinct research domains that every research scientist ought to concentrate on were indicated by the author's keywords and the outcomes of the keyword co-occurrence analysis. More expansive search terms facilitate article retrieval and increase the likelihood of uncovering additional quotations. Keywords provide the advantage of efficiently and promptly guiding researchers to the desired domain while also elucidating the structure of domain knowledge. This research indicates that terms like "lumpy skin disease," "lumpy skin disease virus," and "virus" are among the most frequently occurring keywords when utilizing the author keyword. Furthermore, the evaluation of university collaboration has indicated that the University of Pretoria exhibits the most robust collaborative capacity. Upon analysis of the distinguished research establishments responsible for generating the majority of LSD-related articles, it is noteworthy that these organizations possess an extended research legacy and maintain high standing across diverse domains. Other bibliometric studies show that South African universities are very productive establishments. The results showed that LSDV research has also significantly benefited from the work of Russia's Federal Centre for Animal Health, and Zagazig University, in contrast, did not have an established network of collaboration with other universities. For this study, the partnership between authors from different institutions or universities was defined as "university collaboration." This was determined by the number of papers related to LSD that were co-authored by collaborators. The visualization of international collaboration networks is represented by lines, where the width of each line corresponds to the quantity of these collaborations. Previous research findings (Fan et al., 2020; Igwaran and Edoamodu, 2021) corroborate these conclusions.

Statistics analysis suggests that the total number of citations for the most highly cited papers in this study is crucial due to the high quality of the documents. It is important to note that the number of citations may vary depending on the articles or the search engine from which the documents are retrieved. South Africa ranked first on the list with 792 total citations, demonstrating the highest author country production in LSD studies. This can be attributed to the abundance of publications and collaborations in South Africa and its robust research infrastructure. This analysis used bibliometrics to assess the international network of co-authors. The collaborative network of the thirty most relevant African nations, as documented in the LSD literature, is illustrated in Figure 7. The findings reveal that South Africa and the UK had the most substantial international collaborations in LSD publications. It was also evident from the keyword co-occurrence analysis results that scientists have a wide range of interests. "Lumpy skin disease virus" and "Lumpy skin disease" were most often utilized. As previously explained, the size of the circles in the author keyword co-occurrence networks corresponds to the number of articles containing the author's keyword. The strength of the link indicates the frequency with which the two keywords appear together. This analysis focuses on bibliometric networks, with a particular emphasis on node clusters demonstrating numerous co-occurrences. Furthermore, co-word analysis is utilized to discern the relationships between subjects within a research field, providing insight into the monitoring of scientific progress. In the study of each bibliometric network, nodes sharing a significant number of co-occurrences were grouped and appropriately color-coded to represent their interconnectedness visually (Ogunsakin et al., 2022).

Study strength

This study provides a comprehensive overview of the current research trends in LSD. It includes the analysis of LSD-related publication distribution over time, trends across different countries, the most cited journal, popular keywords, and prominent authors. This research is particularly valuable as it presents the first bibliometric analysis of LSD publications. By encompassing most published articles related to LSD, this analysis offers a comprehensive list of the most cited journals, countries, papers, and relevant authors. In addition to offering a thorough global research summary, this study identifies and evaluates highly cited publications and authors. This is of paramount importance as the trajectory of any field is often shaped by a select number of influential works and authors (Müller et al., 2018). The findings of this study underscore the importance of conducting LSD research using a comprehensive methodology that integrates systematic reviews with bibliometric analyses. Before the final examination, the literature was meticulously reviewed to ensure comprehensive coverage of relevant documents, and our search strategy was refined to this end. Additionally, a systematic approach was employed in screening papers, contributing to our confidence in identifying the majority of LSD research papers. A comprehensive global analysis was performed to assess productivity trends in LSD research. This analysis was conducted to provide additional data support and to offer a thorough understanding of the field. Furthermore, VOSviewer software was utilized to create visual representations for the study. The Heyat group previously used this software to determine the closest terms in the following domains: deep learning in motor imagery (Pal et al., 2023), female disorders (Sultana et al., 2022), bruxism (Heyat et al., 2020), insomnia (Bin Heyat et al., 2020), stress with machine learning (Akhtar et al., 2020), deep learning in motor imagery (Guragai et al., 2020), augmented reality in education (Sheikh et al., 2021), smartphone addiction (Akhtar et al., 2022), camphor (Fazmiya et al., 2022), blockchain technology in cryptocurrency (Akhtar et al., 2019), and anxiety (Akhtar et al., 2024).

This study also presents data on the prolific researchers and institutions, their publishing journals, popular subjects, and prevalent collaborations. The language of publication is a significant factor, favoring English-written articles. Additionally, the affiliation address of the primary author should align with the research project's identity or the country of conduct. In collaborative publications, the lead author may be located in a different country, which is different from the funding source and principal investigator.

Applications of the study

An in-depth bibliometric analysis of LSD offers a comprehensive overview of the current landscape in a given field while assisting in the identification of areas for further exploration, trends, and focal points within LSD research. This method allows for the pinpointing of areas that necessitate heightened attention and support and shapes research objectives through an examination of publication and citation patterns. This approach gauges the effectiveness of research endeavors by assessing the impact of research on the scientific community, policymakers, and practitioners. Consequently, it provides an evidence-based understanding of the field's current status, facilitating well-informed decision-making and the formulation of policies for the control and management of LSD. Moreover, it enables collaboration and knowledge sharing by identifying key researchers, institutions, and countries involved in LSD research. Bibliometric analysis assists in monitoring research progress over time and evaluating the effectiveness of research strategies and initiatives. It identifies knowledge gaps and directs future research towards a more targeted approach to addressing LSD-related challenges. This analysis informs resource allocation by understanding research output and impact, ensuring that funding and resources are directed to priority areas. Applying bibliometric analysis in LSD research is a valuable tool for the scientific community, policymakers, and practitioners, ultimately contributing to improved disease management and animal welfare.

Limitations, research gap, and future recommendations

There are various restrictions on this study. Regrettably, this analysis is confined to English-language publications, potentially resulting in the omission of pertinent information in other languages. Oversight in searching for terms found in the summaries led to missing documents containing informative keywords in their titles. It is acknowledged that cross-referencing the citations or reference lists of the eligible documents could have mitigated this oversight, albeit at the cost of reducing the prevalence of false positives in our study. It is important to note that the impact and advancements of an article in a particular field cannot be solely determined by its citation count. The papers obtained for this analysis were exclusively sourced from journals indexed by the Scopus database. This implies that conducting a bibliometric analysis may yield notable differences in outcomes over the course of a few years. The integration of various databases could enhance the accurate representation of content in the field of study, particularly as research in this area continuously expands due to the introduction of new technologies. The superior journal abstract and citation coverage provided by the Scopus database made it the preferred option over other databases such as PubMed and Web of Science (Burnham, 2006; Pranckutė, 2021).

Lastly, it is emphasized that low levels of collaboration and publication in a nation do not necessarily indicate a lackluster body of scientific work. Future bibliometric analyses ought to take these restrictions into account and look more closely at how LSD research has developed. Notwithstanding these drawbacks, the infor-

mation provided by this database encompasses many LSD research publications. Future studies should look into vaccines, antiviral drugs, epidemiological findings, pathogenic mechanisms, etc., and conduct relevant systematic reviews and meta-analyses to identify potential research gaps.

Moreover, there is evidence of collaboration among writers from Australia, the USA, and Africa on LSD research. It is recommended to further facilitate collaboration between these nations and other African countries on research projects. Additionally, partnerships between developing African countries and those with advanced research infrastructure could help improve the low publication and collaboration rates in the former. This research holds the potential for the scientific community to gain insights into prominent publications, authors, academic institutions, and countries involved in LSD research. South Africa and the United Kingdom are the most frequently cited countries, with 792 and 783 total citations, or average article citations of 22.63 and 46.06, respectively, with the Transboundary and Emerging Diseases Journal, which has an h-index of 19, publishing 399 articles. The findings of this study shed light on potential research gaps, providing valuable insights for researchers looking to explore this field further.

Conclusions

This study comprises a comprehensive quantitative and qualitative analysis of prominent journals, highly cited articles, and noteworthy authors in the field of LSD publications. This study utilizes bibliometric analysis for the first time to clarify the progression of research trends in LSD. The findings of this will furnish emerging researchers with an enhanced comprehension of LSD epidemiology, thereby facilitating the advancement of LSD research endeavours. Additionally, the study delves into institutional and international collaboration along with co-occurrence-network analysis, indicating the potential to generate evidenced-based reports, analyses, and visual representations of research findings stemming from LSD research.

Abbreviations

LSD: lumpy skin disease; WOAH: World Organization for Animal Health; ShPV: sheep pox virus; GPV: goat pox virus; CaPV: capripoxvirus; LSDV: lumpy skin disease virus; h-index: Hirsch index; OIE: Office International des Epizooties; TC: total citations; GC: globally cited; LC: locally cited; PCR: polymerase chain reaction; ELISA: enzyme-linked immunosorbent assay; GPCR: G-protein-coupled receptor; PLT: primary lamb testicle; CPE: cytopathic effects; PGT: primary goat testicle; PGK: primary goat kidney; MDBK: Madin-Darby bovine kidney; MCP: multiple country publication; SCP: single country publication.

Author's contribution

H.M.Z.: conceptualization, methodology, formal analysis, software, validation, and writing – original draft; M.B.B.H.: conceptualization, methodology, formal analysis, project administration, resources, validation, and writing – original draft; M.A.B.H. and S.P.: data curation, methodology, investigation, visualization, formal analysis, and writing – review and editing; A.S., F.A., and A.I.: data curation, methodology, investigation, visualization, and writing – review and editing; D.P. and A.A.: conceptualization, formal analysis, funding acquisition, validation, resources, supervision, project administration, and writing – review and editing; R.E.O. and A.S.A.: conceptualization, formal analysis, funding acquisition, resources, supervision, project administration, and writing – original draft. All authors have read and agreed to the published version of the manuscript.

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Competing interests

The authors declare no conflict of interest.

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