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BIBLIOMETRIC INSIGHTS OF THREE DECADES OF CAMEL RESEARCH IN EUROPE WITH AN EMPHASIS ON COLLABORATION, RESEARCH THEMES AND EMERGING TOPICS

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ABSTRACT

Camels are essential to the livelihoods of pastoral communities in dry and semi-arid regions. Although camel research in Europe is not as prominent as in camel-rearing regions, it has gained considerable interest in recent years, focusing on various aspects such as disease transmission, genetics, and the nutritional benefits of camel products. This study aims to conduct a comprehensive bibliometric analysis of camel research in Europe. It evaluates the evolution of this field, emphasizing publication trends, citation impact, collaboration networks and emerging topics. Data was sourced from the Scopus database and 1385 documents were analyzed. The analysis was conducted using VOSviewer and the Bibliometrix package in R Studio. The analysis revealed steady growth in camel research output, with a 5.51% annual increase from 1995 to 2024. A total of 5094 authors contributed to the field, with an average of 22.61 citations per document and 77.69% of documents are from international collaboration. European countries, particularly France, the UK, and Germany acted as key hubs for international collaboration. The bibliometric analysis identified five main keyword clusters in camel research in Europe. These clusters include themes such as camel physiology and veterinary medicine, the nutritional and biochemical properties of camel milk, infectious disease and antibiotic resistance, zoonotic diseases and genetics, and immunology and molecular biology, reflecting the diverse research areas within this field. Future research should focus on expanding sources, including non-English publications, and exploring advanced technologies such as genomics and AI to enhance the understanding of camel biology and its global impact.

Keywords: Camel research, Europe, bibliometric analysis, camel milk, international collaboration, VOSviewer, R Studio, Scopus

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INTRODUCTION

Camels are essential to the livelihoods of pastoral communities in dry and semi-arid areas, helping to ensure food security through milk and meat production and transportation (Adah *et al.,* 2023). According to a study, camels can withstand extreme temperatures and contribute significantly to food security and economic stability (Sahoo 2020). Recent studies also emphasize the significance of camels in disease transmission, notably for zoonotic illnesses like "Brucellosis" and "MERS-CoV", with camels serving as reservoirs for these infections, also pose significant public health challenges (Khalafalla 2023). Furthermore, genetic and genomic research is being conducted to better understand camels' resilience to climate extremes (Al Abri *et al.,* 2023; Iglesias Pastrana *et al.,* 2024).

Camel research in Europe, although not as prominent as in regions where camels are more commonly found, has gained significant interest in recent years. European researchers have contributed to a diverse range of studies, particularly focusing on the camel's adaptation to harsh environments (Almansour *et al.,* 2024), its immune system (Hussen *et al.,* 2024; Lado *et al.,* 2020), and its role as a potential source of therapeutics (Abdulrahman *et al.,* 2016; Flis *et al.,* 2023). Some European studies also examined the nutritional and medicinal benefits of camel products, such as milk, for human consumption (Bilal *et al.,* 2024; Boukria *et al.,* 2023; Darnay *et al.,* 2024; Khalid *et al.,* 2023). Additionally, collaborations with institutions in camel-rearing countries have enriched Europe's research output.

Bibliometric analysis has emerged as a valuable tool for measuring research trends, productivity, and the impact of scholarly work in a range of fields (Almejnah *et al.,* 2023; Alsaleem and Kandeel 2024; Kandeel *et al.,* 2023; Kandeel *et al.,* 2023). This quantitative technique evaluates publishing data, citation patterns, and

collaboration networks to quantify the influence of scientific outputs. A recent study found that it can help understand research dynamics and identify emerging trends (Chen *et al.,* 2023). Bibliographic analysis is a valuable tool for making strategic decisions in science policy and academic publication (Androniceanu *et al.,* 2024).

The study aims to conduct a comprehensive bibliometric analysis of camel research in Europe, providing a detailed analysis of publication trends and the evolution of this field within European publications. It will focus on evaluating key aspects such as collaboration networks, emerging topics, journals, research themes and the identification of the most productive scholars, institutions and countries. Additionally, the study seeks to highlight significant contributions and influential studies that have shaped the trajectory of camel research.

MATERIALS AND METHODS

Data Source and Search Strategy: This bibliometric analysis was based on data from Scopus, a reliable and vast repository of academic publications (Thelwall and Sud 2022). A systematic search was done to locate all relevant papers on camels published in Europe from 1995 to June 10, 2024 (Figure 1).

Camel research was retrieved from studies in Europe including Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom. These countries showed publications recorded in Scopus during data collection.

The search terms and strings include the article titles as follows: TITLE (camel) AND (LIMIT-TO (AFFILCOUNTRY , "Belgium") OR LIMIT-TO (AFFILCOUNTRY , "Bosnia and Herzegovina") OR LIMIT-TO (AFFILCOUNTRY , "Bulgaria") OR LIMIT-TO (AFFILCOUNTRY , "Croatia") OR LIMIT-TO (AFFILCOUNTRY , "Cyprus") OR LIMIT-TO (AFFILCOUNTRY , "Estonia") OR LIMIT-TO (AFFILCOUNTRY , "Finland") OR LIMIT-TO (AFFILCOUNTRY , "France") OR LIMIT-TO (AFFILCOUNTRY , "Germany") OR LIMIT-TO (AFFILCOUNTRY , "Greece") OR LIMIT-TO (AFFILCOUNTRY , "Hungary") OR LIMIT-TO (AFFILCOUNTRY , "Ireland") OR LIMIT-TO (AFFILCOUNTRY , "Italy") OR LIMIT-TO (AFFILCOUNTRY , "Latvia") OR LIMIT-TO (AFFILCOUNTRY , "Lithuania") OR LIMIT-TO (AFFILCOUNTRY , "Luxembourg") OR LIMIT-TO (AFFILCOUNTRY , "Netherlands") OR LIMIT-TO (AFFILCOUNTRY , "Norway") OR LIMIT-TO (AFFILCOUNTRY , "Poland") OR LIMIT-TO (AFFILCOUNTRY , "Portugal") OR LIMIT-TO (AFFILCOUNTRY , "Romania") OR LIMIT-TO (AFFILCOUNTRY , "Serbia") OR LIMIT-TO (AFFILCOUNTRY , "Slovakia") OR LIMIT-TO (AFFILCOUNTRY , "Slovenia") OR LIMIT-TO (AFFILCOUNTRY , "Spain") OR LIMIT-TO (AFFILCOUNTRY , "Sweden") OR LIMIT-TO (AFFILCOUNTRY , "Switzerland") OR LIMIT-TO (AFFILCOUNTRY , "United Kingdom")) AND (EXCLUDE (DOCTYPE , "er"))

Initially, there were 1644 records to evaluate. There was no erratum or duplicate document through filtering. Only English language documents were used in the analysis to avoid misinterpretation from translating other languages. The English articles included were 1579 records, after removing French (23), German (14), Spanish (4), Italian (3), Hungarian (3), Swedish (1), Russian (1), Romanian (1), Portuguese (1), Persian (1), Moldovan (1), Dutch (1) and Croatian (1) articles. Finally, 1385 articles were included in the analysis after excluding 204 articles due to incomplete bibliographic data as missing authors, affiliations or citation data.

Inclusion and exclusion criteria: The inclusion criteria for this study were carefully chosen to enable a thorough examination of camel research undertaken in Europe over the years. (1) Only papers directly linked to camel research written by institutions in Europe were included. (2) The study included a variety of document kinds, such as journal articles, conference papers, reviews, book chapters, notes, and brief surveys, all of which were indexed in the Scopus database and received peer review. (3) To guarantee that the research findings were easily interpretable, only English-language publications were considered. (4) Papers listed in the Scopus database were considered.

The exclusion criteria were (1) Publications not directly related to camel science or written by institutes from Europe were omitted. (2) Any duplicate records or erratum documents, to prevent errors and repetition during the analysis. (3) Papers published in languages other than English were excluded due to probable interpretation concerns.

Data Cleaning and Preprocessing: The Scopus database's CSV file was exported. The data was then cleaned and pre-processed in R Studio to remove duplicates and records that were unrelated to the bibliographic information as previously described (Alsaleem and Kandeel 2024).

Bibliometric analysis: The analysis was performed using VOSviewer "version 1.6.18" and the Bibliometrix package in R Studio "version 3.1.4". VOSviewer was used to generate visual maps containing keyword co-occurrence and thematic clusters, providing a visual representation of the field's intellectual structure and

collaboration patterns. In addition, the R Bibliometrix package was used to conduct further in-depth statistical analyses, such as calculating annual scientific production, publication growth rates, emerging themes, and h-indices (Aria and Cuccurullo 2017; Arruda *et al.,* 2022; van Eck and Waltman 2010).

The bibliometric analysis revealed several key findings, including publication trends over time, author productivity and collaboration patterns, journal impact and relevance, keyword analysis to identify research hotspots, institutional contributions and collaborations, and country-specific research output and collaborations.

Publication Trends Analysis: Analyzing publishing trends can evoke camel research in Europe. This analysis included annual publication output from 1995 to June 10, 2024. Descriptive statistics were employed to provide an overview of the dataset. The results of these investigations were presented using a variety of graphs and charts to effectively depict the trends and patterns observed in Europe's camel research environment.

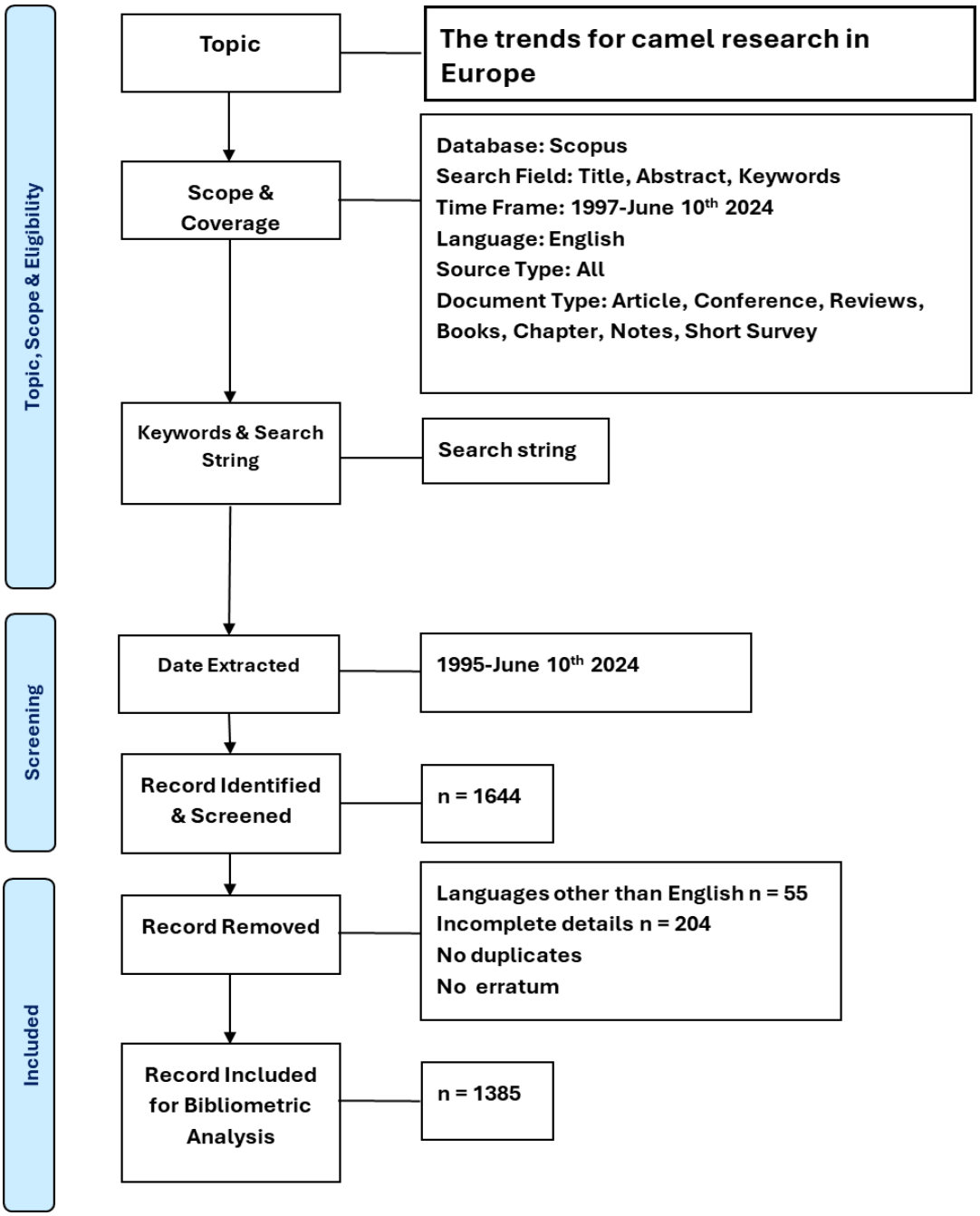

Figure 1. PRISMA flowchart for the bibliometric analysis on trends of camel research in Europe.

RESULTS

Datasets characteristics: The dataset covers camel research from 1995 to June 10, 2024 (Figure 2). The findings show that 601 sources contributed to the 1385 documents created during this time, demonstrating an annual growth rate of 5.51%. This illustrates a steady increase in research production throughout time. This body of work has been contributed to by 5094 authors, 95 of whom have created single-authored works, demonstrating a wide range of contributions from individual scholars to larger collaborative organizations. International collaboration is prevalent in this field, with 77.69% of the studies integrating cross-border co-authorship. On average, each document has 5.93 co-authors. Furthermore, the average age of the papers in this dataset is 10.2 years, and the high average citations per document of 22.61 indicate that the research is significant and well-referenced.

Figure 2: The key statistics in camel research in Europe from 1995 to 2024.

Annual scientific production: The annual scientific production of camel research in Europe has a fluctuating but overall increasing tendency throughout time. In the mid-1990s, research output was minimal, with only 15 papers published in 1995. However, by 1997, there had been a significant surge in interest, as demonstrated by the publication of forty publications. This early growth marks the beginning of increased scholarly interest in camels. Throughout the late 1990s and early 2000s, the number of papers produced per year varied, with some years having lower output levels (less than 40 papers per year).

Starting in 2009, there was a clear increase in research output, with a peak of 109 papers in 2021. Following the peak, output fell slightly but remained much higher than in previous years. Despite these fluctuations, the overall trend shows an increasing and ongoing commitment to camel research, emphasizing its importance in the region.

International collaborations: The country collaboration map of camel research showed a significant concentration of collaborations in Europe, particularly in countries like France, the United Kingdom, and Germany (Figure 3). These countries appear to act as central hubs, connecting with various nations across the Middle East and North Africa. Beyond Europe and the Middle East, the map reveals broad international collaborations spanning continents. There are strong links between European researchers and those in the Middle East, North America, and Australia, illustrating the global nature of camel research.

The VOSviewer graph illustrates the global network of collaborations in camel research, with countries represented by circles and larger circles representing greater research output (Figure 4). Countries like the United Kingdom, Germany and France are important components of this network, serving as major research hubs. These countries have substantial cooperative links with regions in the Middle East, Africa, and Asia, indicating the global scope of camel studies. Furthermore, because of the cultural and economic importance of camels in these regions, countries such as Saudi Arabia, the United Arab Emirates, and Morocco play major roles in the cooperative network. Furthermore, countries such as France and Germany have long-standing collaborations, while newer relationships are emerging with Kazakhstan, Tunisia and Jordan.

Country scientific production of the global contributions to camel research in Europe: The country's scientific production map displays the global distribution of camel-related research contributions (Figure 5). Countries painted in darker blue, such as France, the UK, Germany, the USA, Egypt and Saudi Arabia, provide significant contributions, demonstrating their strong involvement in camel research. France's substantial contribution, although being outside of traditional camel-rearing zones, reflects global academic interest in the issue, which is most likely fueled by

relationships with camel-dependent countries. Saudi Arabia, on the other hand, is well-positioned due to its physical and economic linkages to camels. Other countries, such as the United States, India, and Egypt, have large research output, as shown by the medium blue tones on the globe. Countries with lighter colors or no color indicate regions with lower research output. The highly productive countries in Europe include France, Germany, the UK, Italy and Spain with 550, 394, 381, 251 and 213 publications, respectively.

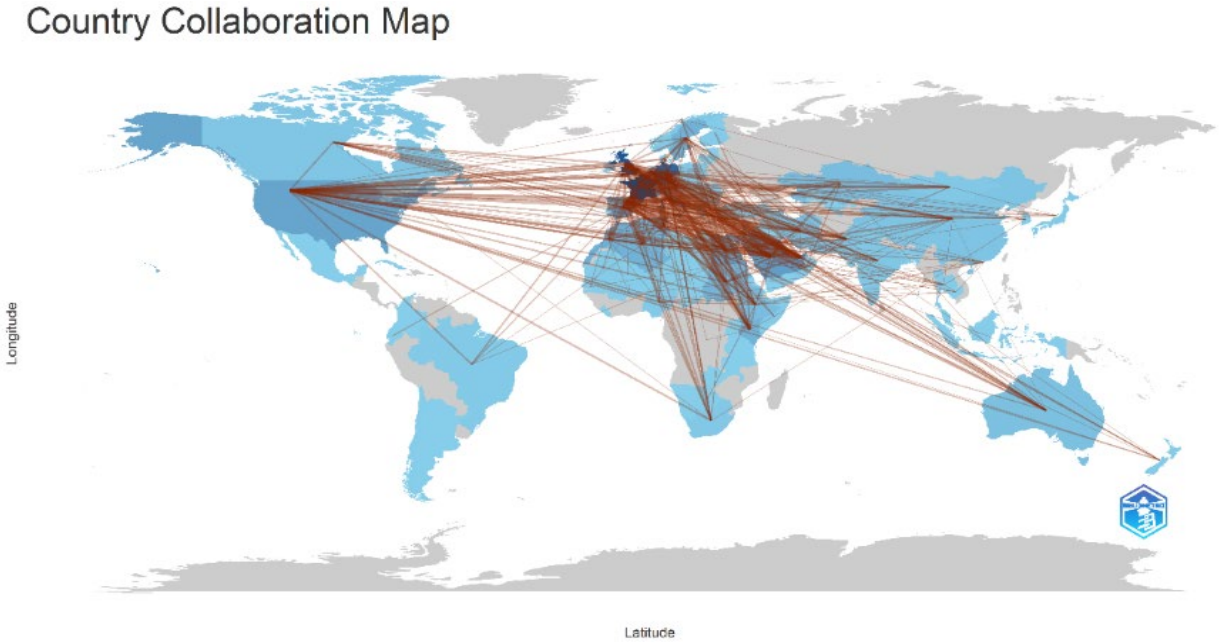

Figure 3. The country collaboration map of the global partnerships and research networks in the field of camel studies.

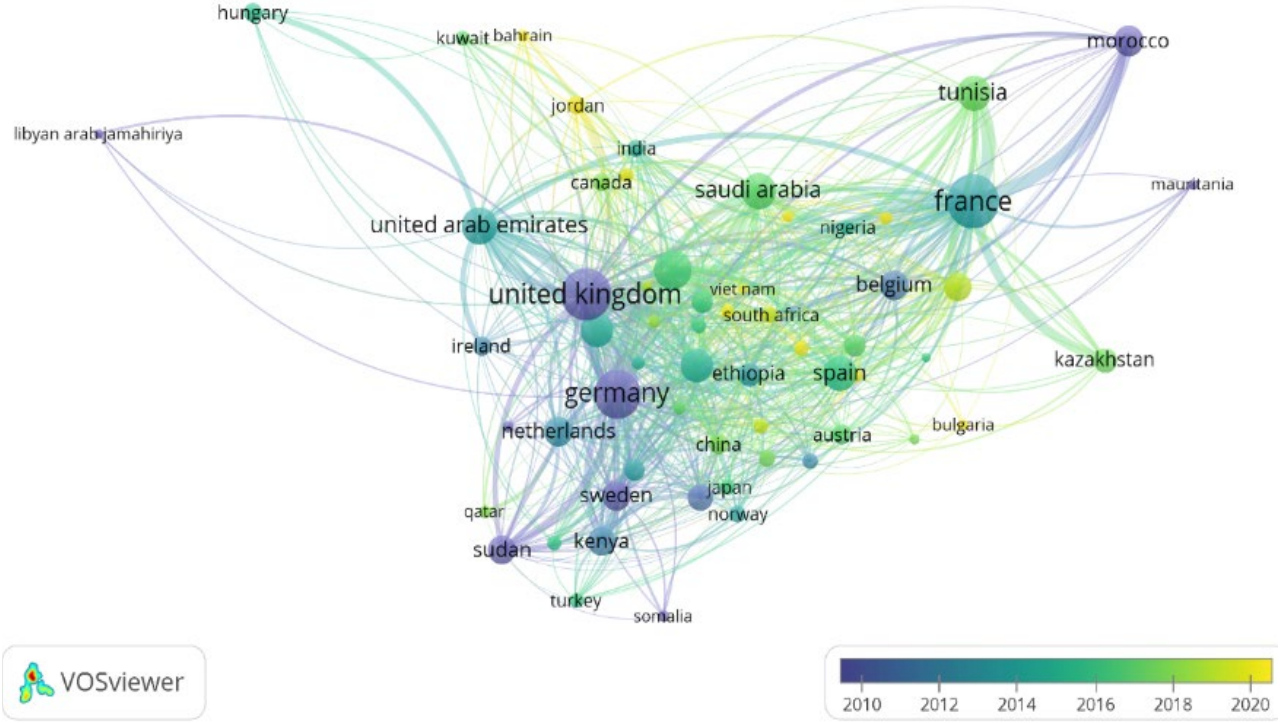

Figure 4: The VOSviewer visualization of country collaborations in camel research in Europe. The color gradient in the visualization represents the timeline of collaborations, with purple indicating older partnerships and yellow representing more recent ones.

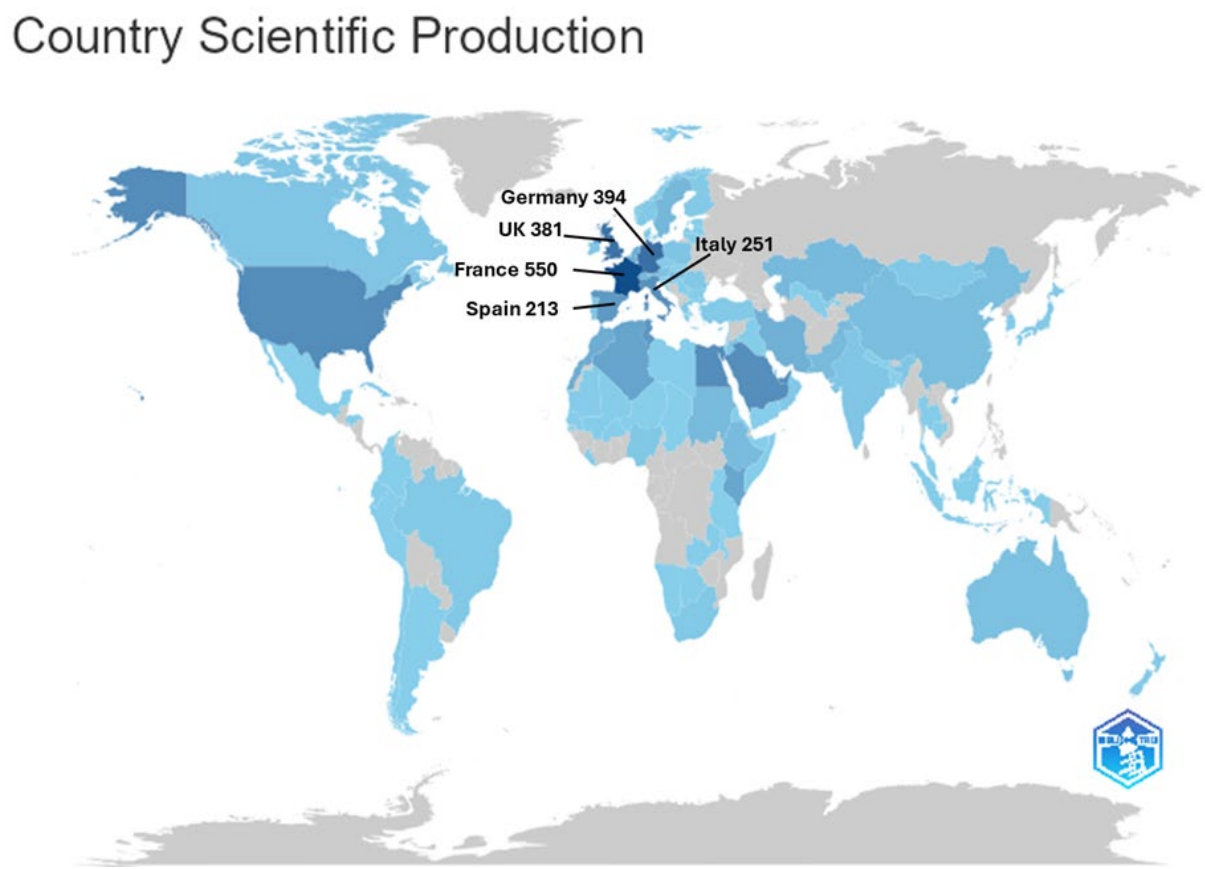

Figure 5: The country's scientific production map representation of the global contributions to camel research in Europe. Dark blue areas indicate higher contribution output, while lighter shades or no color reflect lesser contributions or emerging interest in camel-related studies).

Most relevant publishing journals: The key source for knowledge transmission in this field is The Journal of Camel Practice and Research, which has 107 published papers (Figure 6). This journal is extremely specialized, focusing just on camels, and it is the primary resource for information on camel health, veterinary treatments, and management. The Emirates Journal of Food and Agriculture follows with 51 papers, highlighting its significance in linking camel research to larger agricultural and food production concerns. Furthermore, Tropical Animal Health and Production and Animals, with 47 and 26 articles each, emphasize the interdisciplinary nature of camel research. Other notable sources include the International Dairy Journal and the Journal of Dairy Science which publish 26 and 24 articles respectively, which also contribute to our understanding of camels, particularly in terms of dairy production and nutritional science. Bradford's Law analysis of camel research identifies the important journals that cover the field (Table 1), which showed the core vehicles for camel research in Europe.

Corresponding authors countries: The bar chart (Figure 7) illustrates the number of documents corresponding to the author's country, categorized into Single Country Publications (SCP) and Multiple Country Publications (MCP). The countries on the Y-axis represent the top contributors to scientific publications, with France leading, followed by Germany and the United Kingdom. The X-axis indicates the number of documents contributed by each country. The bars are color-coded, with teal representing SCP and coral representing MCP.

The most relevant authors: Several important personalities in the area are highlighted by the authors' local impact on camel research in Europe, as demonstrated by their number of articles (Figure 8). With over 150 papers since 1997 and an H-index of 30, Faye B is undoubtedly the most active researcher. Konuspayeva G follows with 40 publications. Other important contributors were Bengoumi M, Ayadi MA, Hammadi M, Attia H, Wernery U, Monaco D, Khorchani T and Lacalandra GM.

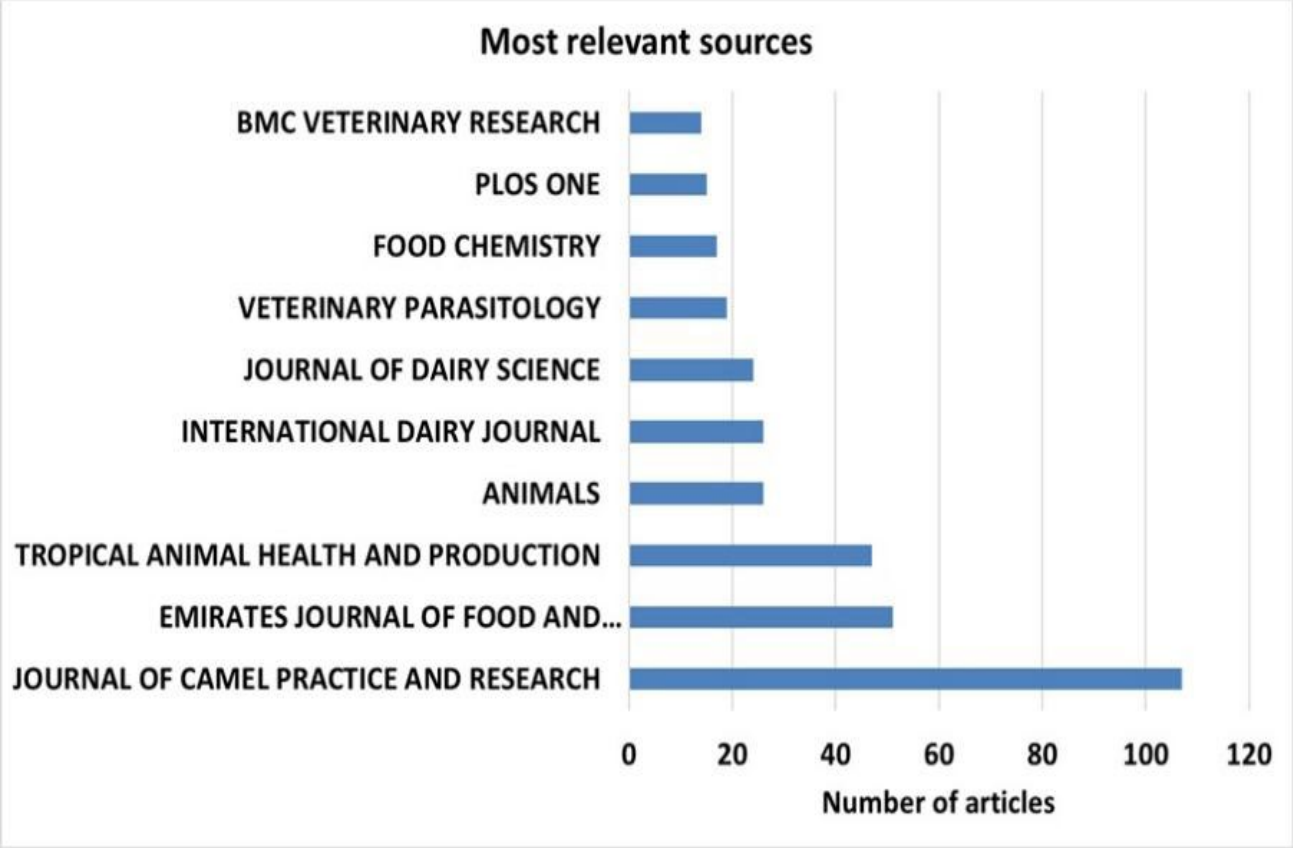

Figure 6: The most relevant key journals in camel research in Europe.

Table 1: Bradford's Law analysis of the core journals of camel research in Europe.

SO	Rank	Freq	Zone
JOURNAL OF CAMEL PRACTICE AND RESEARCH	1	107	Zone 1
EMIRATES JOURNAL OF FOOD AND AGRICULTURE	2	51	Zone 1
TROPICAL ANIMAL HEALTH AND PRODUCTION	3	47	Zone 1
ANIMALS	4	26	Zone 1
INTERNATIONAL DAIRY JOURNAL	5	26	Zone 1
JOURNAL OF DAIRY SCIENCE	6	24	Zone 1
VETERINARY PARASITOLOGY	7	19	Zone 1
FOOD CHEMISTRY	8	17	Zone 1
PLOS ONE	9	15	Zone 1
BMC VETERINARY RESEARCH	10	14	Zone 1
EMERGING INFECTIOUS DISEASES	11	14	Zone 1
FRONTIERS IN VETERINARY SCIENCE	12	13	Zone 1
LWT	13	13	Zone 1
ANIMAL REPRODUCTION SCIENCE	14	12	Zone 1
JOURNAL OF DAIRY RESEARCH	15	11	Zone 1
ANTHROPOZOOLOGICA	16	9	Zone 1
FOODS	17	9	Zone 1
PASTORALISM	18	9	Zone 1
SMALL RUMINANT RESEARCH	19	9	Zone 1
VETERINARY RECORD	20	9	Zone 1
INTERNATIONAL JOURNAL OF DAIRY TECHNOLOGY	21	8	Zone 1

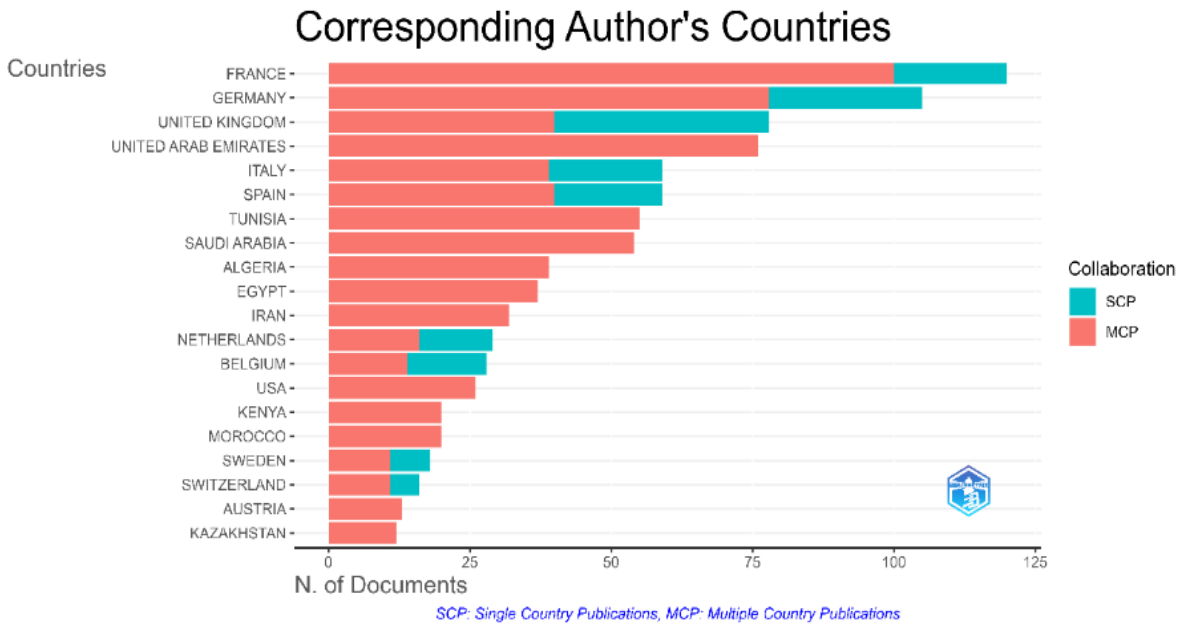

Figure 7. Corresponding authors countries of camel research in Europe.

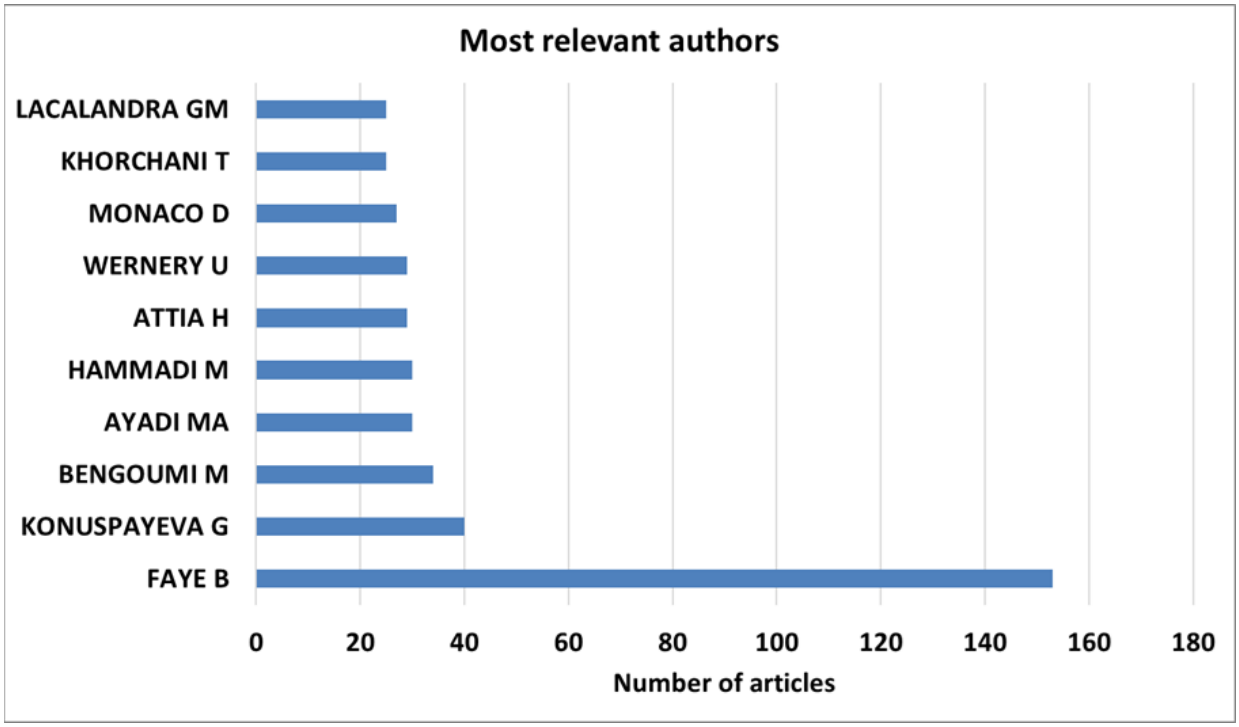

Figure 8: Authors' academic impact in camel research in Europe measured by the number of articles.

Author production of camel research articles over time: The analysis of authors' production over time reveals notable patterns in their contributions to camel research (Figure 9). These data demonstrate the dynamic nature of research contributions, in which the authors may have periods of high output and influence, reflecting shifting trends and interests in camel research. For example, Faye B, Bengoumi M and Wernery U are scholars who have consistently authored publications over the years, with citation counts rising at different times. The number of articles released each year varies, as does the overall citation impact, indicating that certain research works or themes received more attention from the scientific community in particular years.

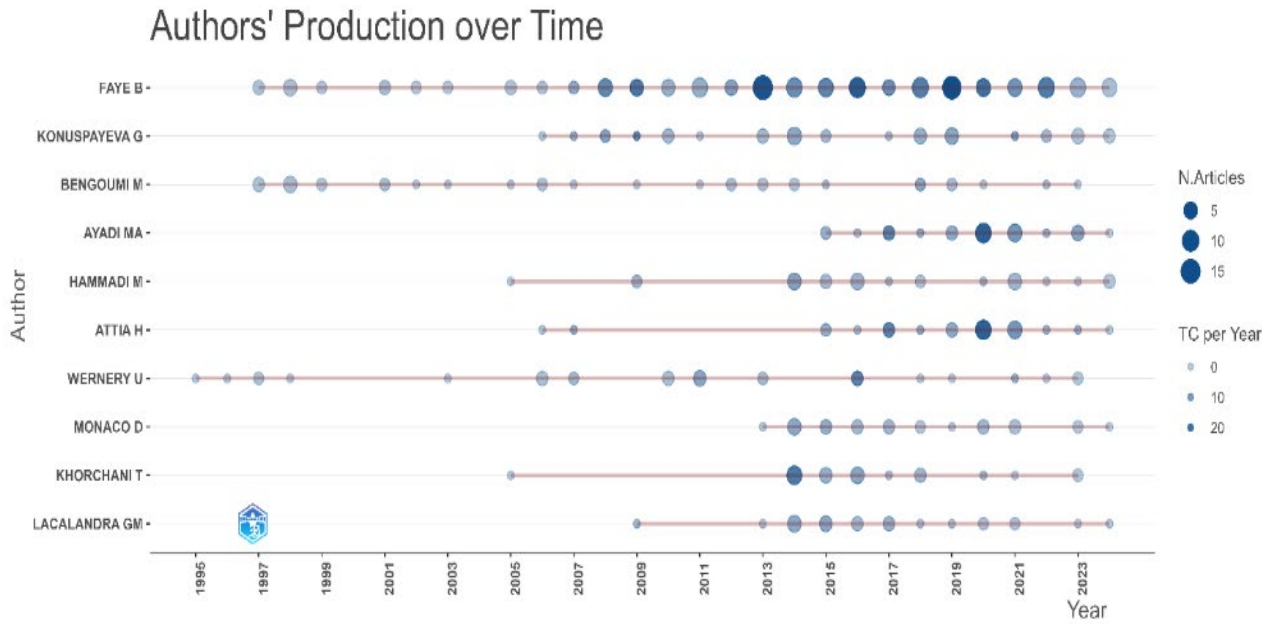

Figure 9: Authors' production of camel research articles over time.

Most cited countries: Belgium showed the highest total citations of 3255 times of citations (Figure 10). France was closely behind with 2900. Germany makes a large contribution, with 2559 total citations. Other notable providers are the Netherlands and the United Kingdom, with 1659 and 1496 total citations, respectively.

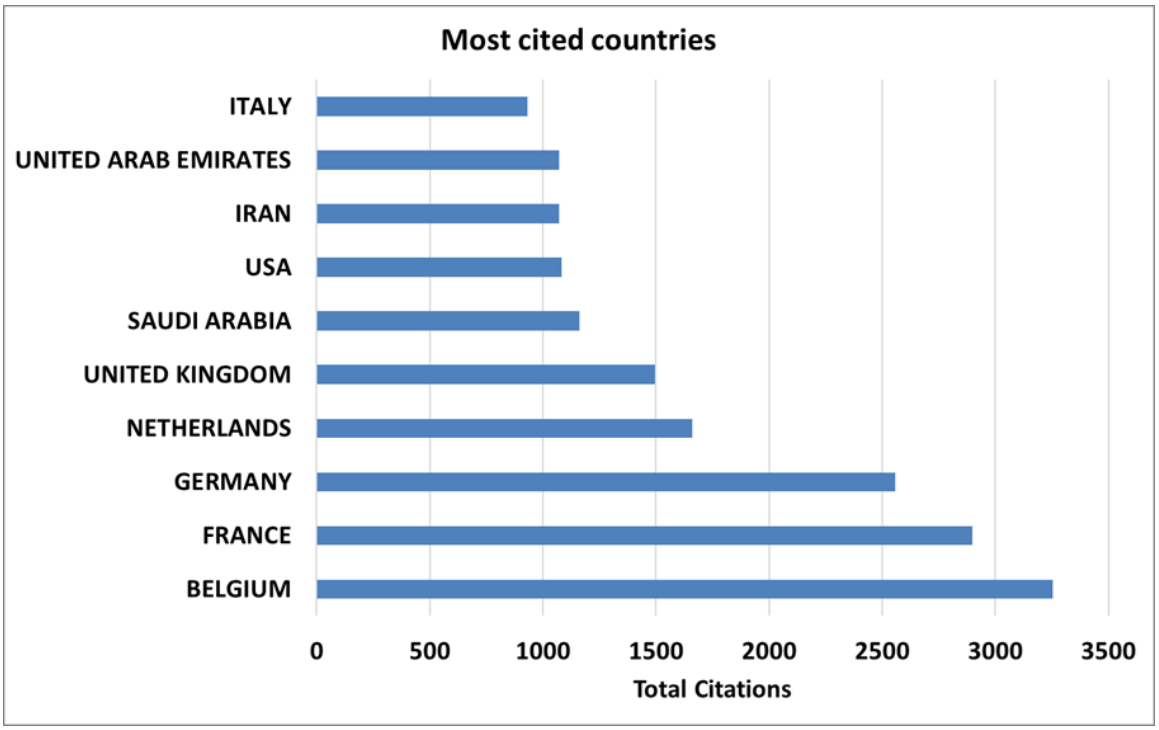

Figure 10: The most cited countries of camel research in Europe.

Most global cited documents: The dataset illustrates some very prominent papers that have affected the field, with Arbabi Ghahroudi M, 1997, FEBS Lett having the most citations (636 total) and an average of 22.71 citations per year (Arbabi Ghahroudi *et al.,* 1997) (Figure 11). Similarly, Reusken CBEM, 2013, Lancet Infect Dis

comes second with 581 citations, but it stands out with a significantly high annual average of 48.42 citations (Reusken *et al.,* 2013), indicating its vital significance in infectious disease research, particularly in recent years. Another significant contribution is the study by Haagmans BL, 2014, Lancet Infect Dis, which has received 525 citations and has a high average of 47.73 citations each year (Haagmans *et al.,* 2014). Furthermore, Muyldermans S, 2001, Rev Mol Biotechnol has accumulated 480 citations (Muyldermans 2001).

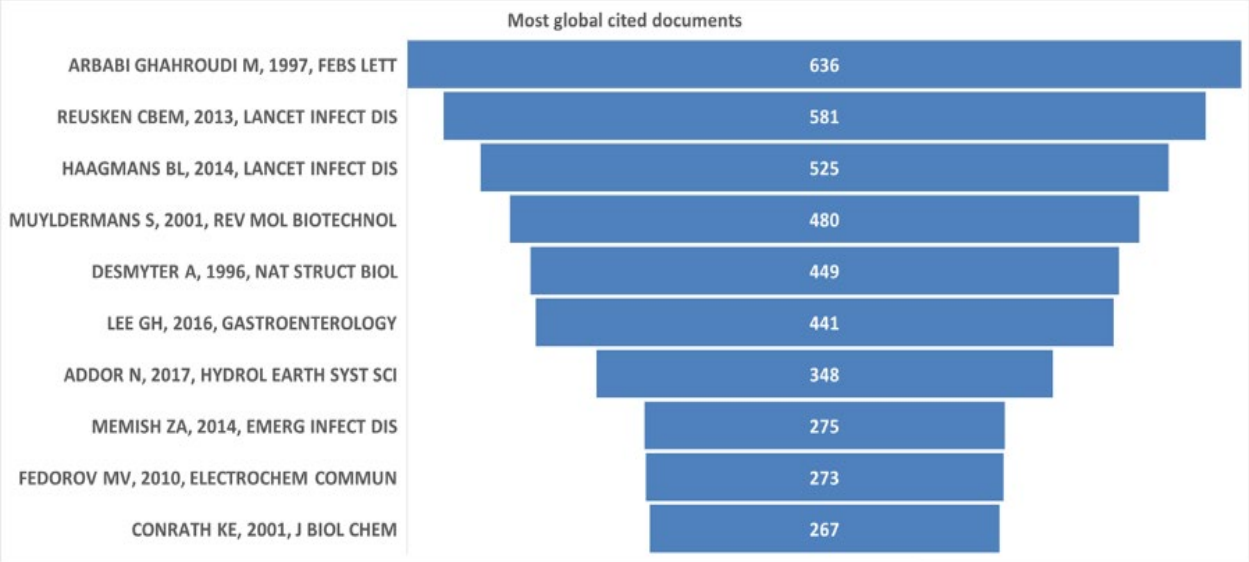

Figure 11: The most globally cited documents in camel research in Europe.

Thematic map of camel research in Europe: Figure 12 depicts a thematic map of major research areas in camel studies, organized by development (density) and relevance (centrality). The upper-right quadrant, known as the motor themes, is notable for the dromedary, *Camelus dromedarius*, and Saudi Arabia. These are well-developed and important topics in the study, indicating the relevance of camel biology and its regional importance, particularly in the Arabian Peninsula. In the lower-right quadrant, basic themes, we find significant yet underdeveloped concerns including camel milk, heat treatment, and camel's milk. These themes are fundamental to the field, but they have not been investigated as thoroughly as the motor themes, indicating possible avenues for future research. Moving to the upper-left quadrant, which symbolizes specialist issues, phrases such as health, welfare, and probiotics denote specialized areas that are well-researched but may not be as interconnected to the larger field. Finally, the lower-left quadrant contains developing or decreasing topics, with phrases such as bioactive peptides and serum indicating areas that are gaining or losing prominence.

Trend topics: Figure 13 "Trend Topics" demonstrates the evolution of several study concerns in camel studies from 1995 to June 10, 2024, as shown by a timeline of words and frequencies. The y-axis contains keywords that represent certain study interests or subjects, while the x-axis depicts the history in years. The size of the circles correlates to the frequency of each term, demonstrating how frequently specific topics appear in the literature over time. As research progressed, particularly after 2010, there was a noticeable trend toward more specific concerns.

Classical Topics: Certain terms, such as "Purification", "Echinoccocus granulosus", "Immunohistochemistry", "Serum", "Dehydration", and "Selenium", appear early in the timeline, indicating long-standing research interests in these areas, comprising biochemical, parasitological and diagnostic approaches.

Emerging Topics: The image depicts emerging topics in camel research, with terms like "antioxidant activity", and "camel milk" becoming more prevalent in recent years. These topics reflect a growing interest in the nutritional and medical benefits of camel products. The most recent usage of flow cytometry in camel health was also presented as "flow cytometry" in the last few years (Hussen *et al.,* 2023; Shawaf *et al.,* 2022).

Most common trends: The most widely used terms, such as "camel milk," "milk," "MERS-CoV," and "*Camelus dromedarius*," indicate a continued scientific focus on camel biology and species-specific studies. The frequent appearance of "camel milk" or "milk" throughout history, particularly in recent years, suggests that it is becoming more acknowledged as an important research topic due to its distinctive characteristics and potential health benefits.

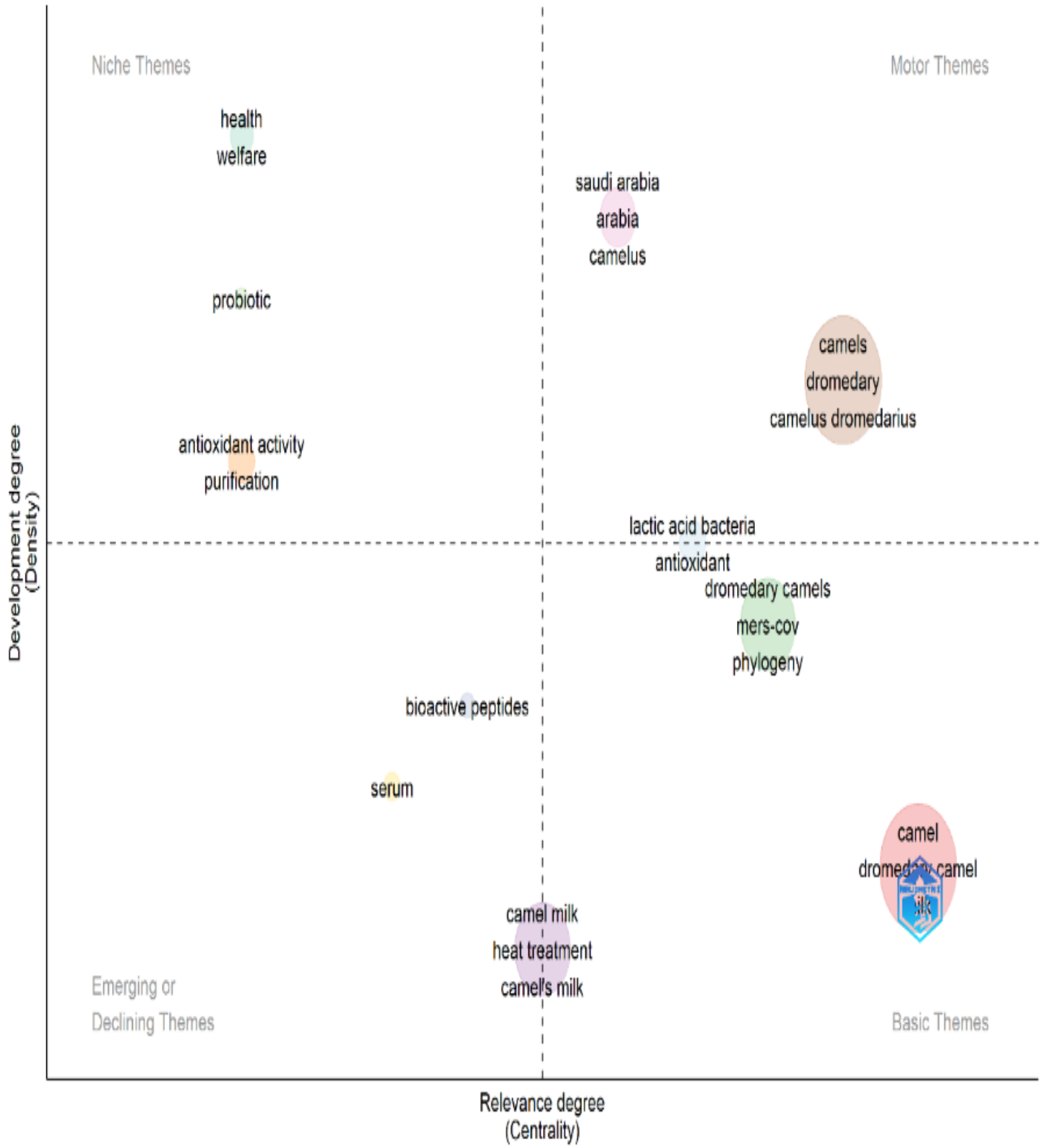

Figure 12: Thematic map of camel research in Europe categorized by their development degree (density) and relevance (centrality). In the upper-right quadrant, the motor themes, which are well-developed and central to the field, the lower-right quadrant, basic themes, the upper-left quadrant, the niche themes section, and the lower-left quadrant represents emerging or declining themes.

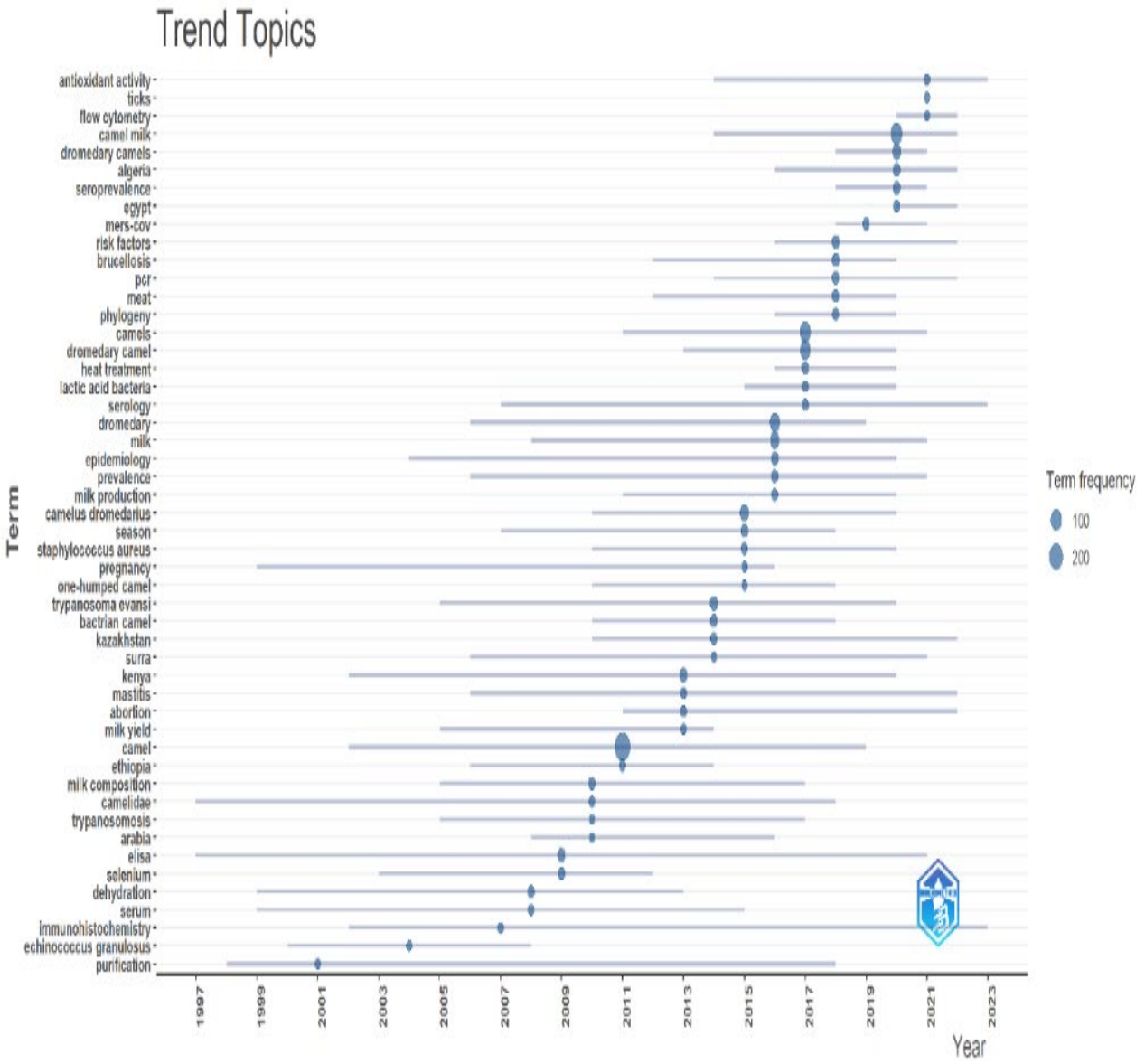

Figure 13. The trending topics of key terms in camel research in Europe over time.

keywords co-occurrence: We may classify the camel research in Europe based on keywords co-occurrence (Figure 14) into the following clusters:

Cluster 1: The cluster (red Cluster) contains, camelus, female, physiology and veterinary medicine. It examines the physiological characteristics of female camels (Camelus), focusing on reproductive biology, metabolic processes, and adaptations to their environment.

Cluster 2: This cluster (green cluster) investigates the composition, characteristics, and chemical analysis of milk, specifically camel milk, with a focus on its nutritional value and the biochemical processes involved in its production and preservation. It also includes milk protein, lactoferrin and antioxidant activity, indicating the therapeutic and protective aspects of camel milk. This reflects the strong interest in studying the health benefits and chemical composition of camel milk.

Cluster 3: This cluster (blue cluster) investigates the connection of microbiology, veterinary medicine, antibiotic resistance, and disease prevalence, with a focus on infectious diseases in animals, particularly camels, as well as the growing concern about bacterial resistance to antibiotics in veterinary settings.

Cluster 4: The yellow cluster on zoonosis, people, genetics, and seroprevalence denotes a focus on evolutionary and genetic research into the bacteria that cause camel diseases, with an emphasis on transmission dynamics between

camels and humans, as well as genetic factors influencing disease frequency.

Cluster 5: This cluster (purple cluster) is concerned with immunology, the study of mammals (Mammalia), human cell biology, fossils, and molecular components such as antibody interactions and amino acid sequences, with a special emphasis on the relationships between evolutionary biology, immunological responses, and genetics.

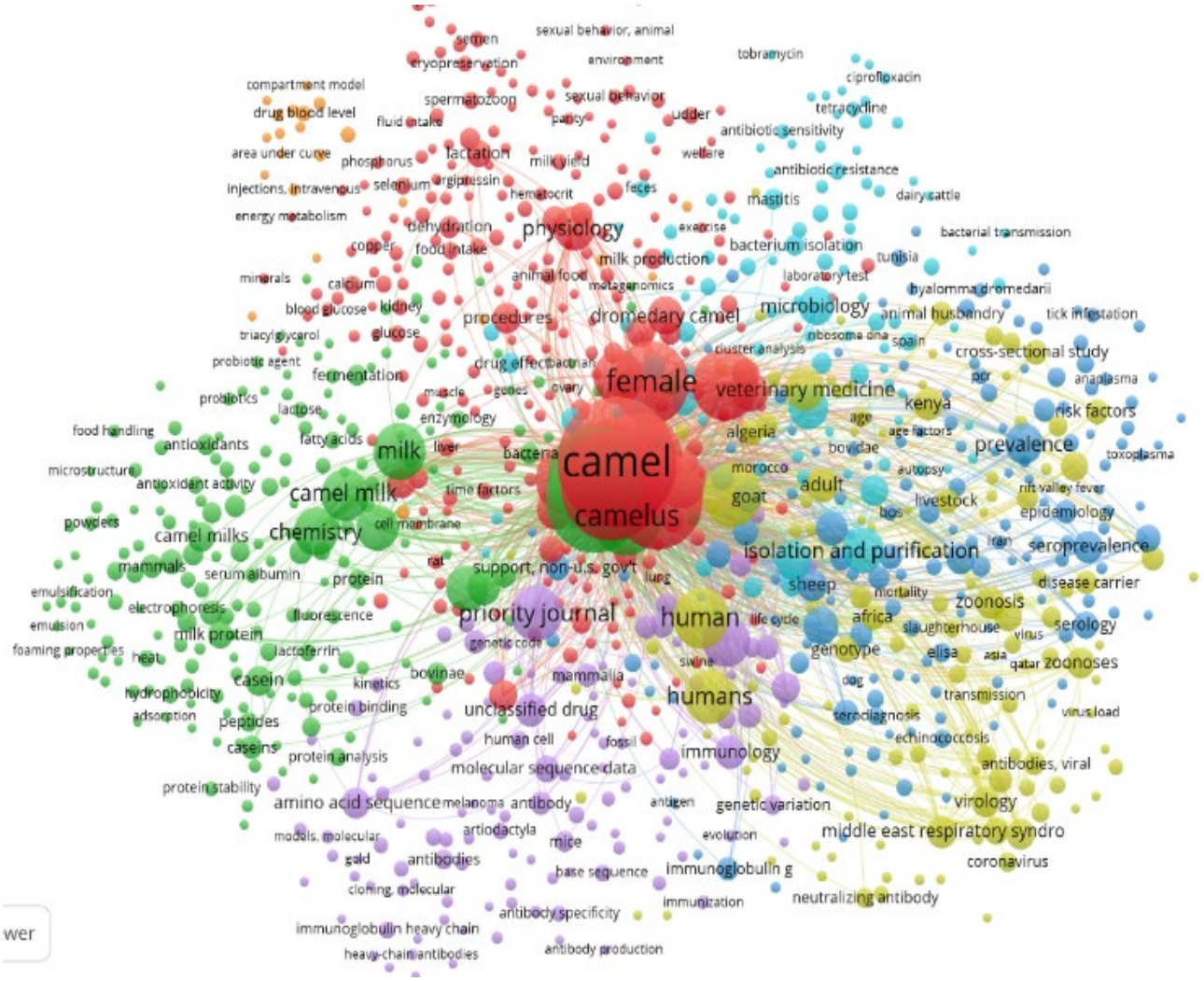

Figure 14: The VOSviewer visualization of the thematic clusters in camel research of Europe with a detailed map of the major topics and their interconnections within the field. The larger nodes represent the most frequently used keywords. The lines connecting the nodes indicate co-occurrence relationships, and the clusters (in different colors) represent thematic groupings of related research topics.

Progression of research topics in camel research in Europe: The overlay visualization represents the colour map of the research time frame (Figure 15). The color gradient represents trends and changes in study focus throughout time. It goes from blue (older themes, around 2005) to yellow (newer topics, around 2020).

The early research (highlighted in blue) appears to have concentrated on basic issues such as camel physiology, reproductive biology, and veterinary procedures. The yellow-colored emerging research themes pertain to more specialized fields like seroprevalence, antibiotic resistance, zoonotic infections, and genetic studies of camels and the microorganisms that harm them. Besides, the chemistry of camel milk such as bioactive compounds including antibodies and amino acids. These allow for a rising multidisciplinary approach that combines traditional veterinary studies with new molecular tools, indicating a shift from basic veterinary care toward more complicated challenges involving public health and genomics.

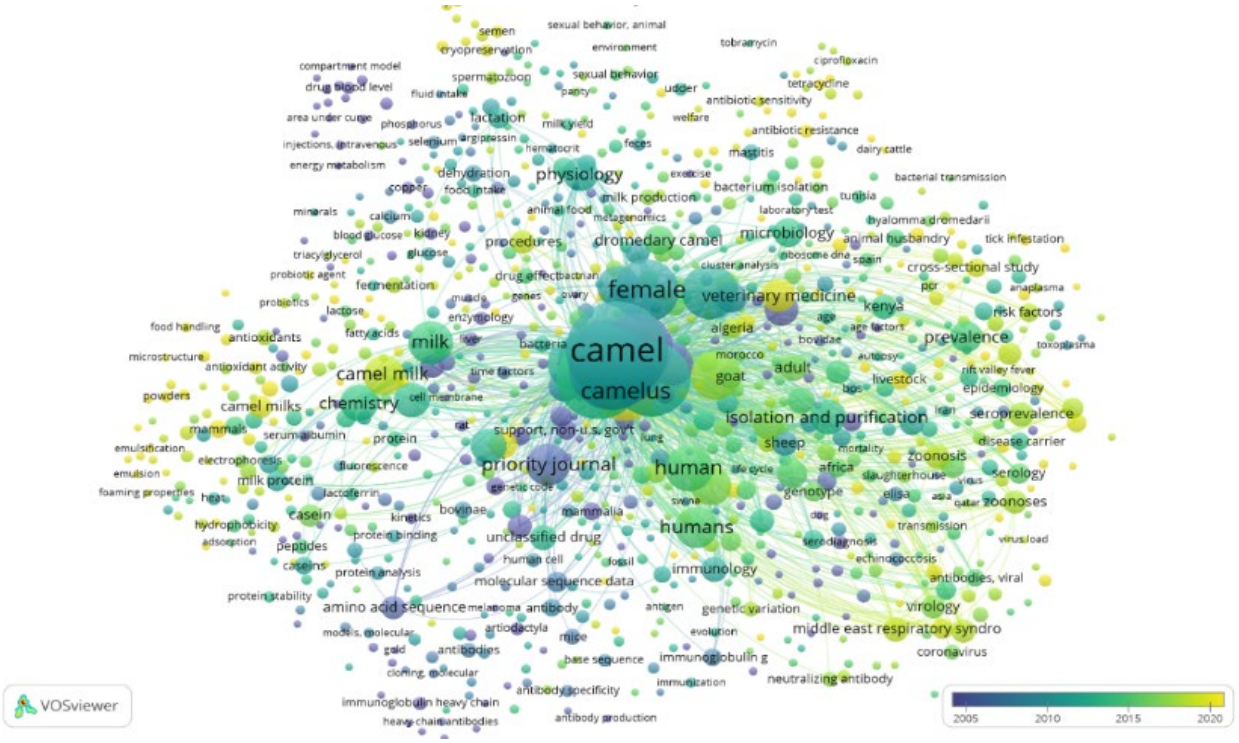

Figure 15: VOSviewer of the progression of camel research topics in Europe over time. It is represented by a color gradient through which blue colouration is concerned with classical topics, while yellow colour is confined to recent topics.

Three field plots: The three-field plot (Figure 16) depicts the relationships between countries, institutions, and key study fields in camel studies. On the left, the plot depicts Saudi Arabia, the United Arab Emirates, Germany, France, the UK, Egypt, the USA and Italy as major contributors to camel research, reflecting their strong academic and practical interest in camels. In the middle, key universities such as King Faisal University, King Saud University, and the United Arab Emirates University and the University of Bari stand out, proving their critical role in producing significant volumes of camel-related research. On the right, the research concentrates on issues such as camels, camel milk, and dromedary camels, indicating a strong emphasis on camel biology and products, particularly milk production and species-specific studies of dromedary camels (Bilal *et al.,* 2024; Boukria *et al.,* 2023; Darnay *et al.,* 2024).

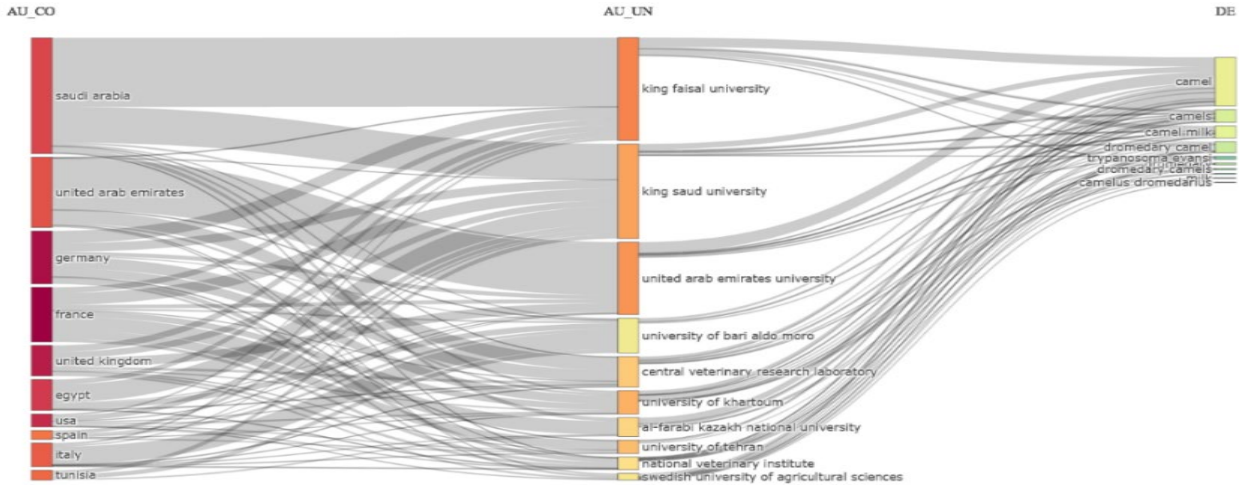

Figure 16: A three-field plot illustrating the relationships between countries (AU_CO), affiliations (AU_UN), and keywords network (DE) of camel research in Europe.

DISCUSSION

The bibliometric analysis of camel research in Europe reveals several important trends and contributions in the field. The steady increase in research output, particularly since 2010, highlights the growing academic interest in camels, driven by their unique biological characteristics and their significance in agriculture, veterinary science, and environmental sustainability. European countries like France, Germany, and the United Kingdom serve as central hubs for international collaborations, especially with regions in the Middle East and Africa where camels are integral to livelihoods. The thematic analysis underscores a strong focus on camel health, disease transmission, and the nutritional value of camel milk, which aligns with the increasing global interest in sustainable agricultural practices and the health benefits of camel products.

Another key finding from the analysis is the shift toward multidisciplinary research. Initially centered on veterinary science and physiology, recent studies have expanded into areas like microbiology, genetics, and oxidative stress, demonstrating a broader understanding of camels' role in both human and animal health. For example, research into zoonotic diseases such as MERS (Chu *et al.,* 2018; Kiyong'a *et al.,* 2020) and Brucellosis (Dadar *et al.,* 2022; Khalafalla *et al.,* 2020) has become increasingly prevalent due to the public health implications of camel populations serving as reservoirs for these pathogens. Additionally, the rising interest in camel milk's biochemical properties, including its antioxidant activity, reflects its potential in both nutritional and medicinal applications (Mejri *et al.,* 2017). Despite camels being traditionally associated with arid regions like the Middle East and Africa, European scientists are contributing significantly to research on their physiology, health, and production (Bilal *et al.,* 2024; Boukria *et al.,* 2023; Dadar *et al.,* 2022; Khalafalla *et al.,* 2020).

Genetic studies on camels in Europe are also advancing, with scientists mapping camel genomes as well as their pathogens to better understand their evolutionary adaptations and identifying genetic markers that could enhance breeding programs for improved disease resistance and productivity (Mohandesan *et al.,* 2017; Zubair *et al.,* 2015).

Cytological research is further uncovering the cellular structures and functions in camels, particularly focusing on their unique blood cells and reproductive tissues (Ali *et al.,* 2008; Melaku *et al.,* 2015), which could have implications for improving their health.

Infectious disease research involving camels has gained momentum due to rising concerns over zoonotic diseases and the role camels may play in transmitting or resisting certain pathogens. European studies are investigating the epidemiology and control of diseases such as Middle East Respiratory Syndrome (Chu *et al.,* 2018; Kiyong'a *et al.,* 2020; Ommeh *et al.,* 2018) and camel pox (Wernery *et al.,* 1997) and other pathogens.

This bibliometric analysis reveals that international collaboration plays a pivotal role in camel research in Europe, as highlighted by 77.69% of the studies are in collaboration with other countries. European researchers, particularly in countries like France, the United Kingdom, and Germany, serve as central hubs for international collaboration, connecting with regions in the Middle East and North Africa where camels are integral to agriculture and traditional livelihoods.

Though both Europe and North America are not typical areas for dromedary camel raising, both have attracted growing study attention in camels. Though there are not large camel populations, scientific research in these areas emphasizes genetics, zoonotic diseases, and the nutritional value of camel milk, so underlining their increasing academic and biomedical relevance. The annual growth rate of camel-related publications was 5.51% in Europe, which is much higher than the rate for North America, which was 1.89% (Alsaleem and Kandeel 2024). This might be derived from the larger number of researchers working in the field in Middle Eastern countries are of European origin and the inherently larger number of researchers working in this field. This was also obvious with a 77.69% collaboration rate in European publications, compared with 52.04% from North America. The estimated growth rate is ultimately much lower than the countries with native camel breads e.g. China (Kandeel 2024) and North Africa (Naji *et al.,* 2024), which showed 8.05 and 7.18%, respectively. Furthermore, the high percentage of international collaboration is a feature for European publications (77.69%). In comparison, countries with native camel breeds showed much lower rates e.g. 16.91% for South Asian countries (Kandeel 2024) and 27.07% for China (Kandeel 2024).

Camel rearing in Europe had passed several milestones. Camels were an essential component of Roman logistics, medieval rituals, and agriculture followed by a decline in the middle ages (Maitra *et al.,* 2025). Recent estimates reveal the presence of 5000-6000 camels in Europe for tourism or camel milk purposes. However, these populations are present in small discrete populations (Maitra *et al.,* 2025). However, rearing camels in Europe is promising since camels are adapted to the harsh environment and perfect animal for sustainable production.

This study identifies a variety of strengths and limits, as well as clear next steps. One of its strengths is its extensive coverage of camel research in Europe, which includes a wide range of topics and keyword analysis. The use of bibliometric tools, such as VOSviewer and the R Bibliometrix package, deepens the

study and allows for a clear depiction of research trends, key contributors, and collaborative networks. Furthermore, the study's emphasis on critical issues such as zoonotic diseases and sustainability underscores its significance in addressing global challenges such as public health and environmental resilience.

However, the study had certain limitations. The focus on English-language publications may result in the elimination of research conducted in other languages, particularly in areas where French or Portuguese are more widely spoken. Furthermore, relying on the Scopus database may exclude crucial studies that are not indexed in Scopus, resulting in an underrepresentation of some areas of research.

The present research outlines several gaps and proposes potential future options for camel research in Europe. One notable omission is the absence of non-English language publications, which restricts the study's reach. Native speakers of these languages can contribute to more focused aspects. Furthermore, relying just on the Scopus database may miss important regional publications and journals, resulting in an underrepresentation of local research activities. Furthermore, while the study focuses on Europe, it does not provide a comparable analysis of other camel-dependent regions, such as North Africa and the Middle East, which face different challenges and research possibilities. Future research should overcome these issues by integrating multilingual studies and expanding the range of data sources beyond Scopus. Including regional databases and journals provides a more complete picture of the research landscape. Comparative studies of Europe and other camel-reliant countries could yield valuable insights into global research trends and collaborations.

Conclusion: Camel research in Europe has expanded significantly as awareness of the camel's growing relevance in biomedicine, veterinary care, and agriculture rises. This bibliometric analysis emphasizes the increasing number of publications, the expansion of international cooperation, and the range of research topics. The research addresses important subjects including camel well-being, zoonotic illnesses, antibiotic resistance, genetics, and the medicinal and nutritional advantages of camel milk. As shown by the growing multidisciplinary character of camel research including immunology, microbiology, molecular biology, and analysis driven by artificial intelligence, there has been a shift toward more sophisticated investigative approaches. With European nations such as France, Germany, and the United Kingdom major hubs for worldwide partnerships, the report emphasizes the critical importance of international cooperation in advancing camel research. Particularly in areas of the Middle East and Africa where camels are essential for livelihoods, these partnerships have enhanced the field of research and enabled the sharing of resources and knowledge. The great frequency of international co-authorship (77.69%) emphasizes the worldwide relevance of camel research.

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