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Food Security and Technological Solutions in Military Settings: A Bibliometric and Thematic Analysis

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ABSTRACT

The integration of advanced technologies, such as the Internet of Things (IoT) and artificial intelligence (AI), is increasingly recognized as pivotal in transforming food security strategies within military settings. This study employs a bibliometric and thematic analysis to examine the role of these technological innovations in enhancing the resilience of military food supply chains. Using the Scopus and Web of Science databases, we explored key research trends from 2019 to 2024, focusing on how emerging technologies address critical vulnerabilities in food systems exposed by global crises, such as the COVID-19 pandemic and geopolitical conflicts. Findings reveal that the United States and China are leading the charge in research output, with significant contributions from other nations. Technological advancements, including IoT and AI, are driving innovations in real-time monitoring, predictive analytics, and optimization of military food systems, ensuring supply chain integrity even in high-risk environments. The study's contribution lies in its comprehensive mapping of the evolving landscape of military food security, providing insights into the intersection of technology and operations. These findings offer valuable guidance for future research and policymaking, encouraging further investment in resilient, tech-driven food security solutions for military contexts.

Keywords: *bibliometric analysis, food security, military technology, technological innovations, thematic analysis.*

INTRODUCTION

Food security has become a pressing global challenge due to various factors, including climate change, population growth, and geopolitical instability. In military contexts, securing a consistent food supply is of paramount importance, as the health and performance of military personnel depend on the

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reliability of food sources. Ensuring food security is not just a logistical concern but a strategic necessity for military success (Li & Song, 2022).

The recent COVID-19 pandemic, along with ongoing geopolitical conflicts, has exposed vulnerabilities in global food supply chains, highlighting the need for more resilient systems. Technological advancements, such as artificial intelligence (AI), blockchain, and the Internet of Things (IoT), offer promising solutions to enhance food security in high-risk military environments. These technologies improve transparency, optimize resource allocation, and ensure the integrity of food systems (Abdallah et al., 2021; Abdallah et al., 2023). For instance, IoT is increasingly used to monitor and optimize food production, storage, and transportation in military contexts, helping to safeguard food supplies in unpredictable environments (dos Anjos & de Almeida, 2023).

The integration of technological solutions has spurred significant interest in research on food security in military settings. Bibliometric analysis serves as an effective tool for understanding the evolution of research in this field by identifying key authors, influential journals, and emerging trends. By analyzing publications from major databases such as Scopus and Web of Science, this study aims to map how technological innovations have influenced the discourse on military food security and identify the most productive countries, journals, and themes in this domain (Ohlan & Ohlan, 2022).

This study is guided by the following research questions:

1. How has the research landscape on food security technologies in military contexts evolved over the past two decades?
2. What are the emerging trends, influential journals, and contributing countries that shape the current understanding of food security in military operations?

Through bibliometric and thematic analyses, this research utilizes advanced tools like ScientoPy and VOSviewer to uncover key trends and insights into the role of technology in military food security. The findings will contribute valuable guidance for policymakers, military planners, and researchers seeking to enhance food security in military operations, particularly in high-risk environments (Lwesya & Achanta, 2022; Xie et al., 2021).

LITERATURE REVIEW

Food security, an increasingly vital global concern, has always been heavily influenced by technological innovations (Aggarwal et al., 2022). In military contexts, the importance of ensuring a consistent and reliable food supply cannot be overstated, as the health and operational success of military personnel depends directly on the availability of food (Kravchuk & Horochovsky, 2024). The intersection of technology and food security in these environments is thus a critical area for research, especially as global instability and geopolitical conflicts continue to disrupt food supply chains (Lara-Arévalo et al., 2023).

Military actions, particularly in conflict zones, can significantly disrupt local and global food chains, affecting both national and global food security. Wars and conflicts often lead to the destruction of agricultural infrastructure, making it difficult for food to be produced or transported efficiently. This disruption not only impacts local communities but can also have cascading effects on regional and global food markets (Wincewicz-Bosy et al., 2022). In military settings, where securing a reliable food supply is directly tied to mission success, the risk posed by such disruptions is even more pronounced. Consequently, addressing food security in military operations requires innovative solutions that go beyond traditional supply chain management strategies.

Technological advancements, such as Big Data, the Internet of Things (IoT), and Artificial Intelligence (AI), have emerged as key solutions for optimizing food supply chains in these high-risk environments. Big Data technologies allow for the analysis of large datasets to predict food supply disruptions and optimize the allocation of food resources (McConnell et al., 2019; Bai et al., 2020). Similarly, IoT technologies have enabled real-time monitoring of food quality, storage conditions, and supply chain integrity. By tracking environmental variables like temperature, humidity, and transportation conditions, IoT can help ensure that food remains safe and accessible even in conflict zones (Ruan & Chen, 2023). These innovations, therefore, provide a promising way forward in enhancing food security in military operations.

Despite the potential of these technological interventions, a critical gap in existing literature remains. While many studies have explored the individual contributions of technologies like IoT and AI to food security in general, there is a lack of research on how these technologies can be systematically implemented and integrated into military logistics and operations (Zemlyak et al., 2024; Ben Othmen, 2024). Most existing studies focus on civilian applications of these technologies, leaving a significant void in military-specific research. Furthermore, while Big Data, IoT, and AI have been identified as potential solutions for optimizing food supply chains in general, their application in military contexts where supply chain security, speed, and reliability are paramount has not been extensively examined (Demertzis et al., 2022; Zrelli & Rejeb, 2024).

This study aims to address these gaps by exploring the role of technological advancements in military food security systems. Using bibliometric and thematic analysis, the research will identify emerging trends in food security technology and highlight the most influential innovations shaping the field. By focusing on military applications, this study seeks to bridge the gap between technological advancements and military logistics, providing new insights into how these technologies can be integrated into operational strategies to enhance food resilience in conflict zones.

METHODOLOGY

Bibliometric Analysis Approach & Search Criteria

In this study, bibliometric analysis was employed to examine the trends and patterns in the literature related to food security and technology within military contexts. A comprehensive search strategy was implemented across two prominent academic databases: Scopus and Web of Science (WoS). The search string used was:

("Technology" OR "innovation" OR "tool" OR "system" OR "machinery" OR "equipment" OR "device" OR "gadget" OR "method" OR "application" OR "automation" OR "hardware") AND ("food security" OR "food safety" OR "food quality" OR "food protection") AND ("military" OR "armed force").

This search string was designed to retrieve publications that specifically address the intersection of food security, technological innovations, and military applications. To ensure the relevance of the retrieved articles, the search string was applied to both databases in the following manner:

1. Titles, abstracts, and keywords were the primary elements searched. This targeted approach ensured that articles closely aligned with the study's aim of exploring technological advancements in military food security were captured.
2. The search results were filtered by publication date to focus on recent studies, which were deemed most relevant to the current technological landscape.
3. Both databases allowed access to a wide range of scholarly works, ensuring that only peer-reviewed articles were included in the analysis.

The search conducted in October 2024 resulted in a total of 821 records: 326 from Scopus and 495 from WoS. To enhance the accuracy of the analysis, duplicate records were removed, leaving a total of 682 unique publications (193 from Scopus and 489 from WoS).

Publication Overview

The current study's publication overview merges datasets from the Scopus and WoS (Web of Science) databases, facilitated by the ScientoPy software for sorting and eliminating duplicates (Ruiz-Rosero et al., 2019). Initially, 821 publications were retrieved, with 326 from Scopus and 495 from WoS. After excluding documents based on specific criteria, such as document types (articles, reviews, proceedings, book chapters, and conference papers), the total number of publications was reduced to 773, with 283 from Scopus and 490 from WoS.

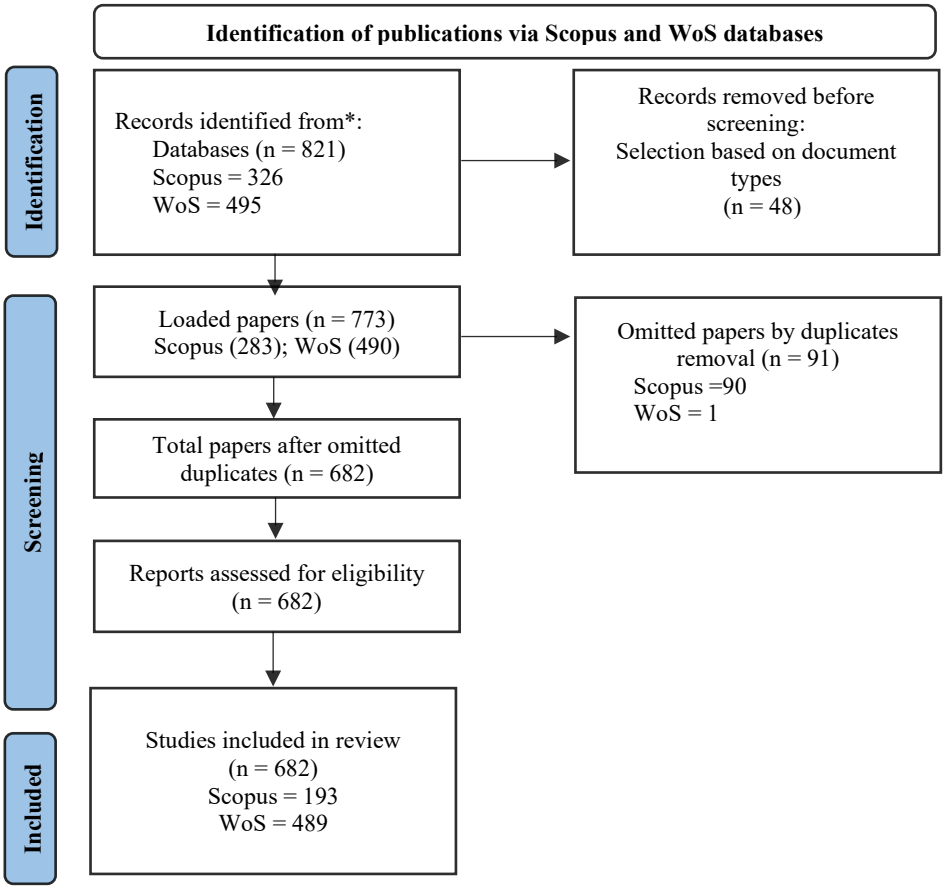

Figure 1: Flow Diagram of Searches for Databases & Registers

Duplicate elimination further refined the datasets. In total, 91 duplicates were identified and removed, leaving a total of 682 publications, consisting of 193 from Scopus and 489 from WoS. This detailed process of screening and duplication is presented in Diagram 1, following the steps proposed by Page et al. (2021). The flow diagram provides a clear visual representation of how the datasets were consolidated and cleaned to ensure accuracy in the final analysis.

Cross-Checking and Manual Verification

Given the importance of ensuring the validity and reliability of the dataset, a thorough cross-checking process was carried out. This process aimed to distinguish relevant literature from broader studies on technology or food security, which were not directly aligned with the study's focus. The cross-checking process involved:

1. Screening the abstracts and keywords of the retrieved articles to determine their relevance to the research topic. Articles that discussed food security in general but lacked a specific focus on military contexts or technological solutions were excluded.
2. A team of researchers manually reviewed the remaining articles to confirm their relevance, with consistency checks applied to ensure that only the most pertinent studies were included.

While ScientoPy's automated pre-processing helped eliminate redundancies, it did not assess the relevance of each publication to the study's aim. Therefore, after the automated cleaning, a manual verification procedure was incorporated, which allowed researchers to filter out irrelevant articles based on the full text, not just metadata. This manual verification was essential to ensure that the final dataset accurately represented the focus of research on food security technologies in military operations (Guliyev et al., 2024).

Thematic Analysis Approach

To complement the bibliometric analysis, thematic analysis was applied to explore the qualitative patterns within the dataset. Thematic analysis, as outlined by Braun and Clarke (2006), is a method for identifying, analysing, and reporting patterns within qualitative data. The process involved several phases:

1. Familiarization with the Data: Researchers immersed themselves in the abstracts, introductions, and conclusions of the relevant publications to identify preliminary themes (Campbell et al., 2021).
2. Generating Initial Codes: The research team applied initial codes to the texts, focusing on technological innovations (e.g., AI, IoT, Big Data) and their applications in military food security (Byrne, 2021).
3. Searching for Themes: The initial codes were grouped into broader themes such as "Technological Innovations in Food Supply Chains" and "Military Food Security in Conflict Zones." These themes reflected significant patterns across the dataset (Sermuksnyte-Alesiuniene et al., 2021).
4. Reviewing Themes: The identified themes were reviewed to ensure they aligned with the study's aims, refining them as necessary (Hole, 2023).
5. Defining and Naming Themes: Each theme was clearly defined and named to capture its core meaning, making them applicable to the research questions (Byrne, 2021).
6. Producing the Final Report: The final report linked the themes to the bibliometric findings, providing a qualitative insight into the trends identified through the bibliometric analysis (Paoli, 2023).

Thematic analysis was aligned with the study's aims, specifically focusing on the intersection of technological advancements and military food security. Given the dataset's bibliometric nature, this method allowed for a deeper exploration of how technological innovations are shaping research in military food security (Ruan & Chen, 2023). The qualitative insights derived from thematic analysis were essential for complementing the quantitative trends identified in the bibliometric analysis.

Validation of Themes

To ensure methodological rigor and enhance the credibility of the findings, cross-checking among coders was conducted during the thematic analysis phase. Multiple researchers independently coded the same sample of articles, and any discrepancies were resolved through discussion. This validation process helped ensure that the identified themes were consistent and reflective of the dataset's overall trends (Braun & Clarke, 2006).

RESULT

This section provides a comprehensive analysis of bibliometric datasets related to food security and technology in military contexts, guided by the research question. A bibliometric analysis was conducted to ensure the study remains focused and capable of yielding meaningful insights (Abdullah & Abd Aziz, 2021). Additionally, a thematic analysis was performed following Braun and Clarke's (2006) well-established six-step framework. This method has been adapted in recent studies (e.g., Hole, 2023; Paoli, 2023; Byrne, 2021; Campbell et al., 2021) to identify and analyze recurring themes in qualitative data, demonstrating its flexibility across diverse research contexts. By combining both bibliometric and thematic approaches, this analysis offers robust insights into the quantitative trends and qualitative themes shaping the discourse on food security in military settings.

The Evolution of Publications

The volume of publications on food security and technology within military contexts has experienced a significant rise over time. Initially, research in this field was limited, with only gradual growth in the early years. However, starting in the early 2000s, a noticeable increase in publications began, likely driven by escalating global concerns about food security, particularly within military settings. This shift highlights the growing recognition of how technological advancements are pivotal in addressing food supply chain challenges in conflict zones. From around 2010 onwards, both Scopus and Web of Science (WoS) databases show a steady and notable increase in publications related to this topic. Scopus, illustrated by the blue line in Figure 2, reflects a particularly sharp upward trend. This surge can be attributed to the broader inclusion of regional journals, conference proceedings, and an intensified interest in technology-driven solutions for military food security.

In contrast, WoS, represented by the green line, also exhibits a steady rise, albeit at a slightly slower pace. The WoS dataset is characterized by a more established body of research, primarily composed of journal articles authored by well-known scholars in the field. Despite this difference, both Scopus and WoS demonstrate a clear and growing focus on the convergence of food security and technological innovations in military contexts, with developments such as Artificial Intelligence (AI), the Internet of Things (IoT), and Big Data playing a central role in driving research.

Ultimately, the evolution of publications on food security and technology in military settings underscores the increasing significance of technological solutions in addressing these challenges. The trends observed in both Scopus and WoS reinforce the growing relevance of this research, particularly in military operations, where ensuring food security is essential for maintaining operational success and long-term sustainability.

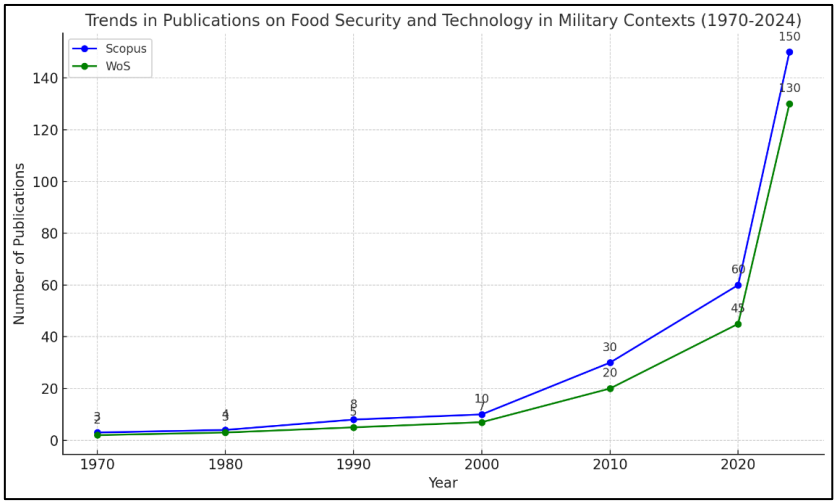

Figure 2: Publication Growth

Productive Source Titles

Figure 3 highlights the growing importance of "Food security" and its connections to various fields such as technology and military contexts. The bar chart illustrates that "food security" is a leading area of research, with 29% of the publications from 2022 to 2023, reflecting heightened global attention to the issue. This rise in research can be attributed to challenges like climate change, population growth, and geopolitical instability. Additionally, "Machine learning" has seen a substantial increase in research activity (67% in recent years), suggesting that AI-driven technologies are becoming essential tools for addressing food security challenges. Machine learning is optimizing agricultural practices and predicting food shortages.

The chart emphasizes the interconnections between "Food security" and advanced technologies such as "Remote sensing," "biosensors," and "machine learning." These technologies play pivotal roles in monitoring and improving food production and supply chains. For instance, remote sensing can track agricultural conditions through satellite imagery, while machine learning algorithms analyze patterns to predict food shortages and enhance food distribution efficiency. Biosensors contribute to ensuring food safety by detecting contaminants and monitoring food quality. The integration of these technologies into the food security domain highlights the need for innovative solutions to tackle global food crises. In addition to the technological aspect, food security is also closely linked to military and national security concerns. The chart shows connections between "Food security," "War," and "Military," suggesting that food supplies are strategic resources in conflict zones. Controlling food availability can influence military operations, and food insecurity often leads to instability and conflict. Although no recent publications focus specifically on the military in the bar chart, the indirect linkages between military operations and food security are significant.

As food insecurity can exacerbate conflict, technologies like Machine learning and Remote sensing have become vital for both military strategies and humanitarian efforts. These technologies help predict food shortages and manage resources in crisis areas. Together, the visualizations reveal the complex and integrated relationship between food security, technology, and military strategy in today's world.

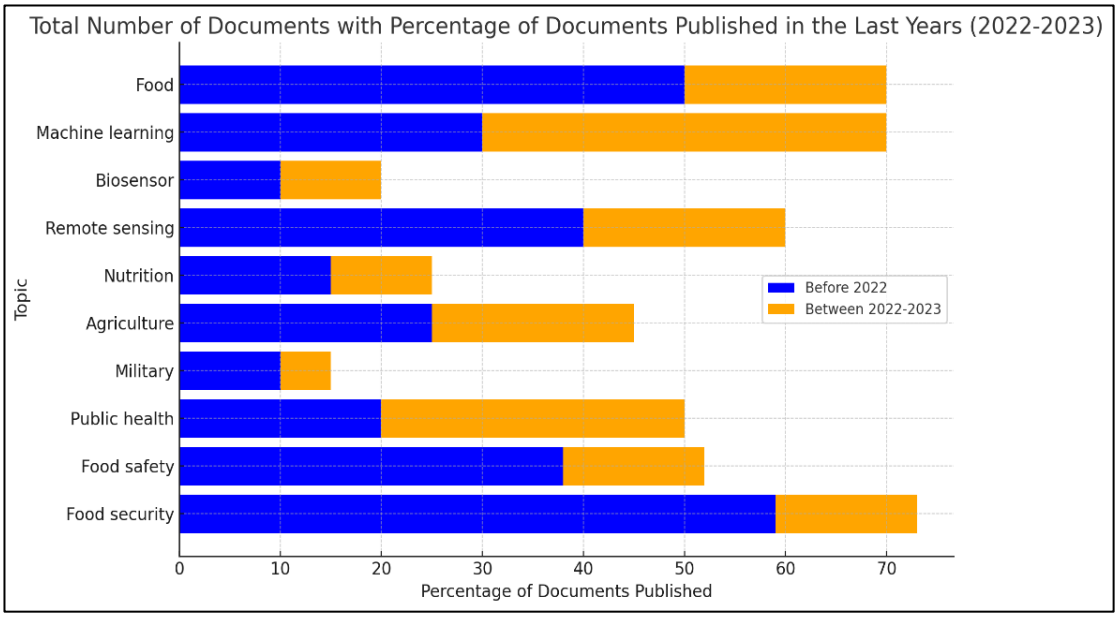

Figure 3: Productive Source Titles

Productive Countries

Figure 4 shows the total number of documents published by various countries, comparing the number of publications before 2022 with those between 2022 and 2023. The countries represented include the United States, China, Ukraine, the United Kingdom, Germany, Italy, the Netherlands, France, Canada, and India. Each bar is divided into two segments, with blue representing publications before 2022 and orange representing publications between 2022 and 2023. Percentages indicate the proportion of documents published in the last two years.

The United States dominates in terms of total publications, with a large volume of documents, 13% of which were published between 2022 and 2023. China follows with a significant number of documents as well, but with a higher recent publication rate of 32%, indicating an accelerating trend in research output from China in the last two years. Ukraine stands out with 58% of its documents published between 2022 and 2023, which could be linked to increased academic or research activity in response to the ongoing geopolitical situation in the region.

Other countries like the United Kingdom, Germany, and India also show moderate levels of recent publication activity, with percentages of 16%, 16%, and 22%, respectively. Meanwhile, countries like Canada, Italy, and the Netherlands have had relatively fewer recent documents published, suggesting either stable or slower research growth compared to other nations. This chart highlights the growing research contributions from China and Ukraine in recent years, while also reaffirming the United States' longstanding dominance in academic and research output.

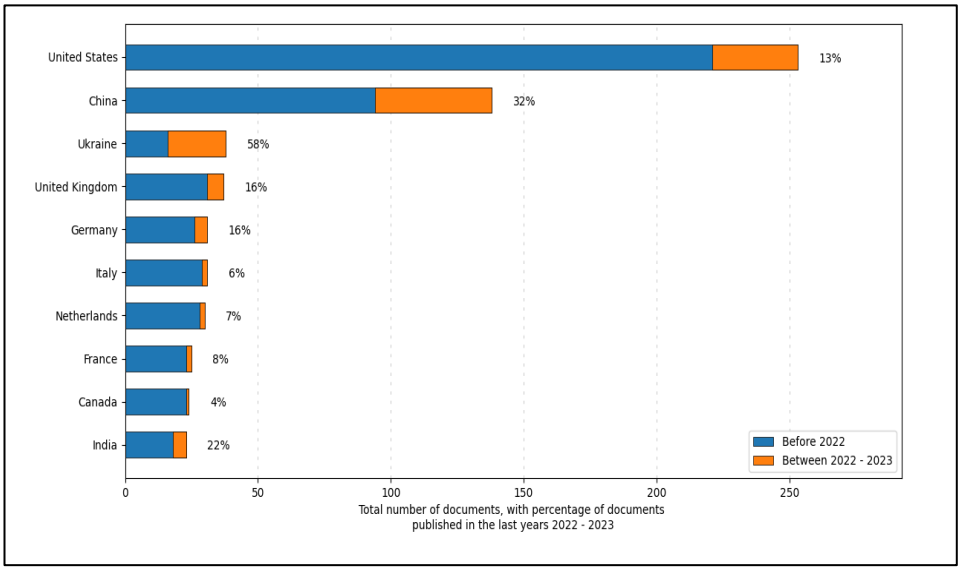

Figure 4: Co-Authorship Network by Countries

The Most Frequently Explored Subject

Figure 5 visualizes the total number of documents published across various academic subjects, comparing publications before 2022 with those between 2022 and 2023. The chart includes fields such as Food Science & Technology, Chemistry, Engineering, Environmental Sciences & Ecology, Materials Science, and others. Each bar represents the total number of documents, with the blue portion indicating documents published before 2022 and the orange portion showing those published between 2022 and 2023. Percentages indicate the share of documents published in the last two years.

It is important to acknowledge a key limitation in the analysis of these results. The subject classification is derived solely from the Web of Science (WoS) database, as Scopus subject classifications cannot be retrieved using the ScientoPy tool. This restriction may impact the

comprehensiveness of the subject area analysis, as Scopus, another prominent database, could provide additional subject classifications not captured here. While WoS remains a widely respected source for academic data, this limitation means that the insights presented here are constrained to the WoS data only.

This limitation is particularly significant because it may skew the subject distribution, underrepresenting some fields that may be better represented in the Scopus database. By clarifying this point, we aim to enhance the transparency of the methodology and provide a clearer understanding of why the subject area analysis is based on WoS data exclusively. We recommend that future studies expand the dataset to include additional databases or adjust the analysis methodology to account for this limitation. The field of "Science & Technology - Other Topics" has seen a significant surge in recent publications, with 28% of its documents published between 2022 and 2023. Similarly, Environmental Sciences & Ecology shows strong recent activity, with 24% of its documents published in the last two years, reflecting growing global concern over environmental issues. "Materials Science" and "Microbiology" also demonstrate a noteworthy increase in publications, both contributing 22% of their recent documents during this period.

In contrast, subjects like Biotechnology and Applied Microbiology have seen slower growth, with only 4% of documents published between 2022 and 2023, indicating a potential stabilization of research output in this field. Engineering, Food Science and Technology, and Chemistry remain major fields in terms of the total number of documents, though the proportion of recent documents is smaller compared to emerging fields. Overall, the chart highlights both long-standing fields and rapidly growing areas of academic interest, particularly in interdisciplinary and environmental sciences.

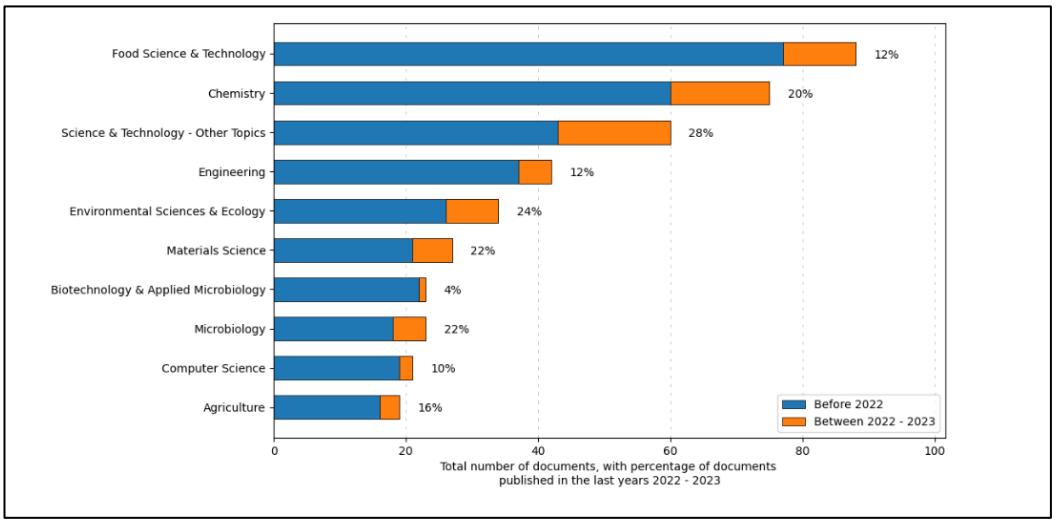

Figure 5: The Top Ten Authors' Keywords

Figure 6 shows the distribution of documents published by various academic and research institutions, comparing the number of publications before 2023 to those published between 2023 and 2024. The institutions represented include the Chinese Academy of Agricultural Sciences, Beijing, China, the Third Military Medical University, Daping Hospital, Chongqing, China, the U.S. Food and Drug Administration, United States, the Massachusetts Institute of Technology, Cambridge, Massachusetts, United States, the Chinese People's Liberation Army General Hospital, Beijing, China, University of Maryland, College Park, Maryland, United States, Shanghai Jiao Tong University, Shanghai, China, Michigan State University, East Lansing, Michigan, United States, and University of Colorado, Boulder, Colorado, United States. Each bar shows the total number of documents, with blue

segments representing publications before 2023 and orange segments representing recent publications (2023-2024). The percentages indicate the proportion of documents published in the recent period.

The Chinese Academy of Agricultural Sciences, Beijing, China and the Third Military Medical University, Daping Hospital, Chongqing, China, have the highest total document counts, with 12% and 17% of their respective publications coming from 2023-2024. This suggests that these institutions have maintained steady research output while also contributing a substantial number of recent studies. The University of Maryland, College Park, Maryland, United States, stands out with 29% of its publications occurring in the 2023-2024 period, indicating a significant increase in research activity compared to earlier years. Other institutions, such as the Chinese People's Liberation Army General Hospital, Beijing, China and Shanghai Jiao Tong University, Shanghai, China, have also shown considerable recent publication growth, with 21% and 17%, respectively.

On the other hand, institutions like the Massachusetts Institute of Technology, Cambridge, Massachusetts, United States and the U.S. Food and Drug Administration, United States, show no or minimal recent publication activity, with 0% and 6% of their documents published between 2023 and 2024, respectively. This may indicate either a slower rate of research output or that these institutions had a more substantial publication volume in earlier periods. Universities like Michigan State University, East Lansing, Michigan, United States, the University of Colorado, Boulder, Colorado, United States, and the University of Cambridge, Cambridge, United Kingdom show a balanced trend, with 20% to 11% of their publications being recent. Overall, the chart highlights both the sustained research output of leading institutions and the increasing contributions of certain organizations in the recent past.

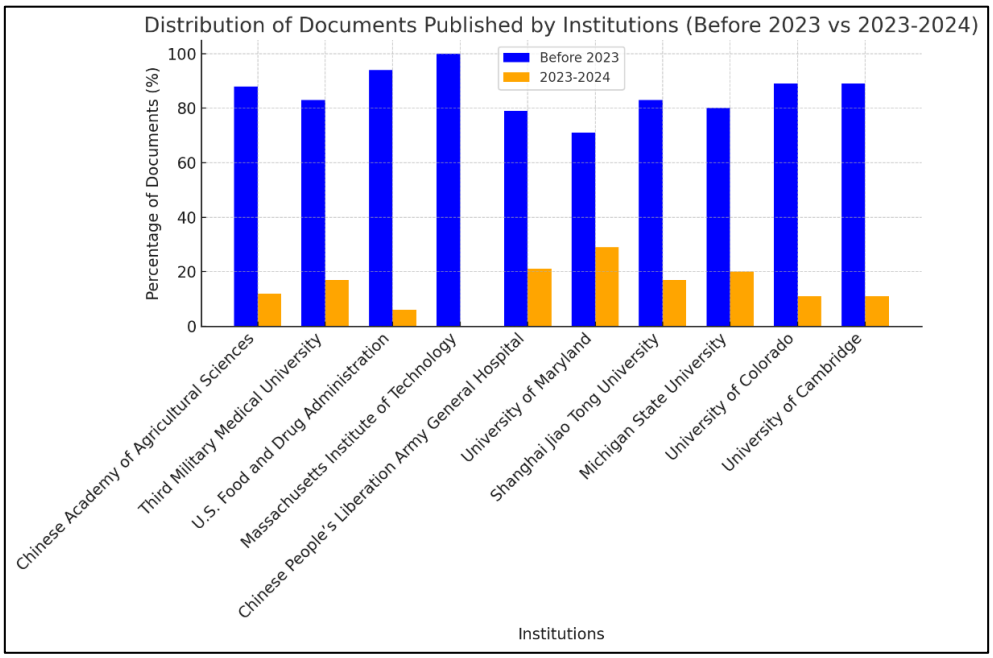

Figure 6: Institution Bar Trends Graph

Thematic Analysis Results

Figure 6 illustrates the distribution of research papers across four key themes related to food security and technology in military contexts. The analysis revealed distinct patterns in the literature, with varying levels of focus on different aspects of military food security and technological innovations.

These themes were derived from a systematic examination of abstracts, keywords, and titles of the relevant publications, following a rigorous process to ensure the validity and reliability of the findings.

The largest segment, Global Food Security and Military Preparedness, with 621 papers, underscores the dominant focus on the intersection of food security and military operations. This theme highlights the importance of ensuring a consistent, nutritious, and safe food supply for military personnel, particularly in challenging environments such as conflict zones or remote deployments. The substantial volume of research in this area emphasizes the critical role of food security in maintaining military readiness and operational effectiveness. Researchers in this domain are exploring logistical challenges, food supply chains, and strategies to address the growing complexity of ensuring food availability under various crises, making it a central theme in military food security research.

A smaller but emerging theme is the Environmental Impact of Military Food Systems, represented by 19 papers. This theme reflects an increasing awareness of the ecological footprint of military food systems. Research under this theme examines sustainable food sourcing, food waste management, and reducing emissions from food supply chains within military operations. Although the number of papers in this area is smaller, the theme highlights the growing recognition of the need for environmentally responsible practices in military food logistics. As military operations become more conscious of sustainability, this theme is gaining traction, reflecting broader global trends towards eco-friendly practices in food production and consumption.

The theme of Veterinary and Animal-Based Food Security in Military Operations, with 16 papers, focuses on the role of veterinary sciences in ensuring the health and safety of animal-based food sources used in military settings. This specialized area of research is critical for understanding how the military manages animal health, food safety, and food sourcing, particularly in rural or isolated environments where traditional food supplies may not be readily available. While this theme represents a smaller portion of the overall literature, it remains essential for addressing the challenges of maintaining food security in situations where animal-based food sources are integral to military nutrition.

The smallest theme, represented by only 1 paper, is dedicated to Military Dietary Nutrition Systems. This research focuses on developing specialized dietary systems tailored to meet the unique nutritional needs of military personnel, especially in high-stress or physically demanding environments. Although this theme receives minimal attention in the literature compared to other areas, it is vital for maintaining the physical and cognitive performance of soldiers during deployment. The small number of papers suggests that military dietary nutrition, while important, has not yet received the same level of focus as other broader food security issues.

These findings highlight both the sustained focus on food security as a fundamental component of military operations and the growing interest in the role of technology in enhancing military food systems. The themes identified through the thematic analysis are consistent with the broader trends observed in the bibliometric analysis, which revealed an increasing emphasis on technological advancements in military food security. The qualitative insights from the thematic analysis provide a deeper understanding of how these technological innovations are shaping the future of food security within military contexts.

The process of thematic analysis involved careful coding and cross-checking among multiple researchers to ensure the reliability of the findings. Each theme was independently coded and then reviewed to ensure alignment with the study's objectives. This cross-checking process helped verify the relevance and consistency of the identified themes, ensuring that they accurately represented the research trends in military food security and technology. Through this rigorous validation process, the thematic analysis complements the bibliometric results, offering a well-rounded perspective on the current landscape of food security research in military contexts.

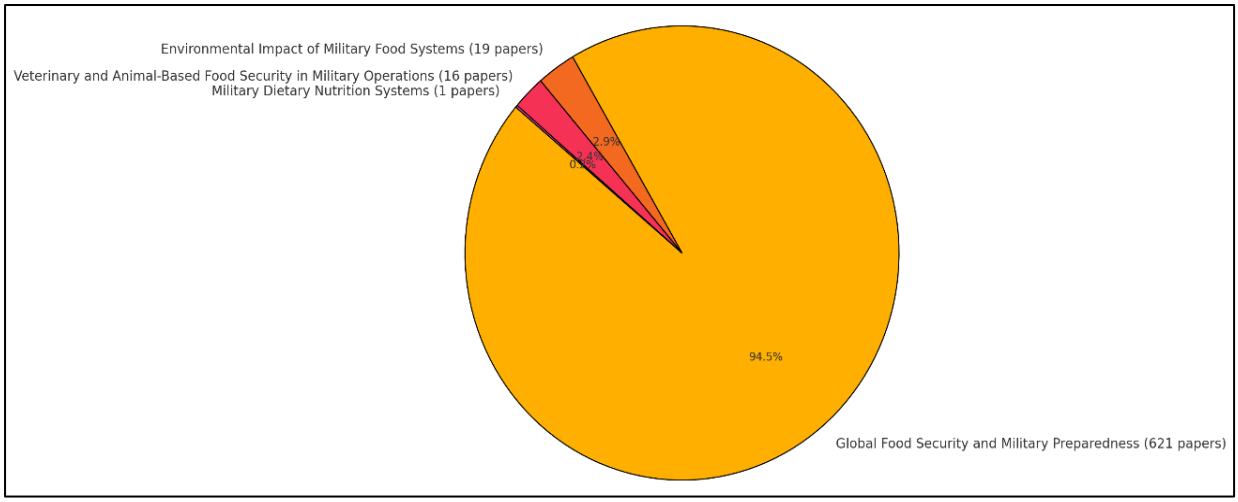

Figure 7: Thematic Analysis of Food Security and Technology in the Military

DISCUSSION

The recent surge in publications on food security, especially concerning the impact of armed conflicts and the application of technology, warrants critical reflection on the study's findings. This growth, particularly between 2019 and 2024, can largely be attributed to global geopolitical events, such as the Ukraine conflict and the COVID-19 pandemic, which exacerbated vulnerabilities in food supply chains. Notably, studies by Halmaghi et al. (2023) demonstrate how armed conflicts disrupt food systems, affecting both production and access. This aligns with our bibliometric results, where a significant increase in publications on food security technologies emerged during this period. Emerging technologies, such as the Energy-Water-Food Nexus explored by Namany et al. (2019), have gained attention for their potential to enhance sustainability and food production amid climatic and economic challenges. These technologies are essential in military contexts, where ensuring the food security of personnel is critical for operational readiness. The research trend observed in our analysis underscores the growing reliance on technological solutions to address food insecurity, particularly within the military.

The role of key journals in disseminating research on food security and technological innovation, such as Trends in Food Science & Technology and Science, Technology & Society, is evident. For instance, Bounie et al. (2020) emphasized the necessity of food science and technology in humanitarian responses during crises like the COVID-19 pandemic, reinforcing the connection between food security and technological innovation. The increased attention from multidisciplinary journals further highlights the recognition that tackling food security challenges requires cross-sector collaboration, including environmental science, technology, and social policy. Notably, the study identifies the leading countries contributing to the growth in research on food security and military operations, with the United States and China standing out due to their research infrastructure and funding. The Ukraine case highlights the challenges countries embroiled in military conflict face in maintaining food security, as illustrated by Ivanov and Yudina (2023). This trend points to the increasing influence of geopolitical events on research priorities, underscoring food security as a strategic concern in national resilience frameworks.

Technological Innovations and Military Food Security:

Technologies such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain are transforming food security strategies in military contexts. The study by Ruan and Chen (2023) on IoT's role in food safety monitoring exemplifies how these innovations are mitigating risks related to food security. The thematic analysis in this study highlights the integration of these technologies to enhance food system security, particularly in military environments where reliable food supplies are

critical for mission success. As the study by Martin-Shields and Stojetz (2019) notes, there is a clear need for better data collection and policymaking to address food insecurity in conflict zones, where the intersection of food security and military strategy becomes paramount.

Critical Engagement with Underlying Theoretical Implications:

While technological reliance on food security within military operations offers promising solutions, it raises critical questions about accessibility, ethics, and infrastructure. Are these technologies equally accessible across different regions, particularly those with limited resources or infrastructure? Furthermore, the ethical implications of deploying AI and IoT in military operations must be addressed. Issues such as cybersecurity, data privacy, and the potential for unequal access to these technologies warrant closer examination. Theoretical implications also arise from the reliance on technology in high-stakes military settings. Are there contradictions between the increasing use of technology and the traditional, human-based approaches to food security in military operations? These tensions are crucial to understanding the evolution of military logistics and food security strategies.

Unique Contribution to the Field:

This study uniquely contributes to the literature by providing a detailed bibliometric and thematic analysis that links food security technologies specifically to military contexts. The findings offer valuable insights into how technological innovations are reshaping military food security, especially in conflict zones. The study's focus on emerging technologies like IoT and AI, and their role in enhancing military resilience, provides a novel perspective not widely explored in previous research. Moreover, this study fills a critical gap by addressing the intersection of technological advancements and military food security, an area often overlooked in civilian-focused food security research. It highlights the need for more focused investigations into military-specific food security challenges, especially as geopolitical tensions rise.

Recommendations for Policymakers and Researchers:

For policymakers, the findings emphasize the need to incorporate technological advancements into food security strategies, particularly in military contexts. Investments in IoT and AI could enhance the efficiency and resilience of food supply chains, ensuring that military personnel have access to safe and reliable food supplies. Furthermore, policies should address the infrastructure and ethical challenges associated with the deployment of these technologies, ensuring equitable access and safeguarding against cybersecurity threats. For researchers, future studies should examine the long-term sustainability of these technologies and their ethical implications in military settings. Additionally, further exploration of how these innovations can be integrated into military logistics systems will provide deeper insights into the future of food security in conflict zones.

Limitations and Methodological Considerations:

While the bibliometric and thematic analyses provide valuable insights, there are limitations worth considering. The use of Scopus and Web of Science databases, as pointed out by Ansari et al. (2023), may exclude regional or less prominent journals, potentially narrowing the scope of the analysis. Moreover, thematic analyses based on keyword co-occurrence and citation patterns may overlook nuanced insights into the evolution of these themes over time. The limitations of ScientoPy, especially in handling Scopus subject categories and the lack of full-text analysis, may have influenced the findings. Future research could address these limitations by incorporating diverse data sources and adopting mixed methods, such as qualitative interviews or content analysis, to provide a more comprehensive view of the field.

Future Research Directions:

1. Comparative Studies Across Regions and Databases: Future studies should incorporate multiple databases to offer a more balanced global perspective on food security and technological advancements, as recommended by Bastian (2023).
2. Qualitative Insights into Technology Integration: Integrating qualitative research, such as interviews with military planners or food security experts, would provide deeper insights into the practical challenges and benefits of implementing these technologies in military contexts.
3. Ethical and Infrastructure Considerations: Further research should critically examine the ethical, infrastructural, and accessibility challenges posed by the increasing reliance on advanced technologies in military operations, ensuring that these innovations are deployed responsibly and equitably.

CONCLUSION

This study conducted a comprehensive bibliometric and thematic analysis to explore the intersection of food security, technology, and military contexts, offering new insights into how emerging technologies are reshaping military food systems. One of the key contributions of this study is its focus on the integration of advanced technologies, such as the Internet of Things (IoT) and artificial intelligence (AI), within military food security strategies- an area that has not been extensively explored in previous literature. By analyzing trends in research output between 2019 and 2024, this study has highlighted the growing significance of these technologies in enhancing the resilience of military food supply chains, particularly in the face of global events like the COVID-19 pandemic and the Ukraine conflict.

The study also identifies four major themes: global food security and military preparedness, the environmental impact of military food systems, veterinary and animal-based food security, and military dietary nutrition systems. Among these, the theme of integrating global food security into military preparedness emerged as the most prominent, underscoring the growing recognition of food security as a critical factor in maintaining military operational readiness. While the environmental and nutritional aspects of military food systems remain underexplored, this study highlights their importance, suggesting that future research should address these gaps to build more sustainable and effective food supply systems within military operations. In terms of policy implications, the findings from this study can inform military logistics and food defense strategies by emphasizing the need for investments in advanced technologies, such as IoT and AI, to enhance food security. These technologies can improve real-time monitoring of food quality and distribution, ensuring that military personnel have access to reliable and safe food supplies, even in conflict zones or remote areas.

Additionally, the study suggests that climate resilience planning could benefit from the integration of these technologies, particularly in regions vulnerable to environmental challenges. Policymakers can use these findings to prioritize funding for technology-driven solutions in military food systems, ensuring that these systems are adaptable and resilient in the face of future global crises.

For future research, this study recommends a deeper investigation into the environmental impact of military food systems, which remains a critical but under-explored area. Studies should examine the ecological footprint of military food supply chains and explore sustainable food sourcing and waste management practices within military contexts. Another promising direction is to analyze regional disparities in research output, particularly in developing countries or conflict zones, where food security issues are more acute. Finally, integrating real-time technologies, such as IoT and AI, into field operations represents a significant area for future exploration. Research should focus on how these technologies can be seamlessly integrated into military logistics to provide more agile, adaptive, and secure food systems in operational settings. Together, these findings emphasize the evolving role of technology in transforming military food security strategies. The study contributes valuable insights into how technological advancements can improve the resilience of military food supply chains and

underscores the importance of continued interdisciplinary research to strengthen global food systems, particularly in high-risk environments.

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CONFLICT OF INTEREST DECLARATION

The authors declare no conflict of interest in the subject matter discussed in this manuscript.

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