Available online at
https://borneoakademika.uitm.edu.my

Borneo Akademika
Volume 9(2) December 2025, 24-41
DOI

e-ISSN: 2735-2250

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

Mohamad Azli Razali[1*], Elias Md Radzi[2], Farina Nozakiah Tazijan[3], Hussin Khan Rahmatullah Khan[1], Norrina Din[1], Khairul Hidayat Rezo[1], Noorliza Zainol[1]

[1]*Faculty of Hotel and Tourism and Management Universiti Teknologi MARA, Pulau Pinang Branch, Permatang Pauh Campus Malaysia*
[2]*School of Business Management, UUM College of Business, Universiti Utara Malaysia, Sintok Kedah Malaysia*
[3]*Academy of Language Studies, Universiti Teknologi MARA, Shah Alam Campus, Selangor Malaysia*

*mohamad080@uitm.edu.my

Received Date: 1 June 2025
Accepted Date: 1 October 2025
Published Date: 10 December 2025

ABSTRACT

Food security and technology have become increasingly important in military contexts, especially as global events such as the COVID-19 pandemic and geopolitical conflicts highlight vulnerabilities in food supply chains. This study aims to explore the intersection of food security technologies within military operations through a bibliometric and thematic analysis. Conducting a bibliometric analysis provides a structured view of research trends, identifying key authors, influential journals, and emerging themes, ensuring the study's focus and relevance. The study used Scopus and Web of Science databases to gather publications, with data analyzed using tools like ScientoPy and VOSviewer for visualization. The bibliometric analysis focused on examining global research output, leading countries, and technological advancements in food security, while the thematic analysis employed Braun and Clarke's (2006) six-step framework to identify recurring themes and patterns. Key findings indicate a surge in publications on food security in military contexts from 2019 to 2024, driven largely by technological innovations such as the Internet of Things (IoT) and artificial intelligence (AI). The analysis also revealed that the United States and China lead in research output, while emerging research themes focus on global food security, the environmental impact of military food systems, and the role of technology in enhancing operational readiness. This study contributes valuable insights into how technological advancements are shaping the future of food security in military operations, offering guidance for future research and policymaking in high-risk environments.

Keywords: Food security; military technology; bibliometric analysis; thematic analysis, technological innovations.

INTRODUCTION

Food security, defined as the availability, access, and stability of food systems, has become a critical issue due to the increasing complexities posed by climate change, population growth, and geopolitical instability. In military contexts, securing a consistent food supply is essential for operational success, as the health and performance of military personnel depend on reliable food sources. Recent advancements in technology, including blockchain, artificial intelligence (AI), and

the Internet of Things (IoT), have introduced innovative solutions to bolster food security in high-risk environments, particularly within military operations (Li & Song, 2022).

The global COVID-19 pandemic has further exposed vulnerabilities within food supply chains, prompting researchers to explore technological interventions to enhance supply chain resilience. Digital innovations such as AI and blockchain have gained traction for their potential to improve the transparency, efficiency, and security of food systems, especially in critical settings like military operations (Abdallah et al., 2021). Consequently, a surge in publications has emerged, reflecting the urgent need for interdisciplinary approaches to addressing food security challenges in military contexts (Dos Anjos & Almeida, 2023).

Bibliometric analysis serves as a powerful quantitative tool to assess the evolution of research on food security and related technologies. By identifying leading authors, influential journals, and emerging trends, this method provides a structured view of the research landscape. It also allows for a better understanding of how innovations in technology reshaping discussions on food security are, particularly in military applications (Ohlan & Ohlan, 2022). These insights are critical as they inform both future research and practical strategies for ensuring secure food supply systems in the most challenging environments.

With increasing attention on the intersection between food security and military logistics, this study addresses the following research question: How has the research landscape on food security technologies in military contexts evolved over the past two decades, and what are the emerging trends, influential journals, and contributing countries that shape the current understanding of food security in military operations?

Using bibliometric and thematic analyses, this study leverages advanced tools like ScientoPy and VOSviewer to examine key trends, identify productive countries, and highlight emerging themes in food security technology research. By analyzing data from major databases, this study provides a comprehensive overview of how technological innovations are being employed to enhance food security, particularly in military contexts, and offers insights into future directions for research (Lwesya & Achanta, 2022).

Ultimately, this study aims to provide valuable guidance for policymakers, researchers, and military planners as they seek to develop resilient, technology-driven food security systems that can withstand global challenges. The insights derived from this research will help shape future strategies to ensure the stability of food supply chains in high-stakes environments (Davis et al., 2020).

LITERATURE REVIEW

Food security is increasingly influenced by technological innovations such as the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain technology, particularly within the context of military operations. Recent bibliometric studies indicate that technological applications play a critical role in enhancing operational readiness and resilience in food supply chains. One of the most significant innovations is the use of IoT to monitor and optimize food production, storage, and logistics, which is pivotal in military settings where ensuring a consistent food supply is crucial (Ruan & Chen, 2023). The integration of IoT technologies allows for real-time data collection and analysis, which can lead to improved decision-making and resource allocation, ultimately enhancing the efficiency of food supply chains in military contexts (Sermuksnyte-Alesiuniene et al., 2021).

The evolution of food security research has been marked by a growing interdisciplinary approach that integrates agriculture, environmental science, and technological advancements. A bibliometric analysis reveals that this trend is particularly strong in regions like the United States and China, which lead research output on these topics. The convergence of these fields fosters innovative solutions that can address food security challenges in various sectors, including military operations. The collaborative nature of this research is essential for developing comprehensive strategies that enhance food security in conflict-prone areas (Mastos & Gotzamani, 2022).

The ongoing conflict in Ukraine has underscored the strategic importance of food security in military operations. Military actions disrupt local food chains, affecting both national and global food security (Wincewicz-Bosy et al., 2022). Innovations such as Big Data and IoT are increasingly

utilized to optimize food supply chains in high-risk environments. These technologies facilitate better decision-making and resource allocation, ensuring that food supplies are maintained even amidst conflict (Toromade et al., 2024). Furthermore, the integration of AI and blockchain technologies is critical in mitigating the impacts of climate change on food security, as these innovations can enhance the efficiency and transparency of food supply chains (Kaur et al., 2022).

Climate change poses a significant threat to food security, particularly in military contexts where operational conditions can be unpredictable. Bibliometric studies suggest that technological solutions, including AI and blockchain, are essential for addressing these challenges by improving food supply chain resilience (Lamberty & Kreyenschmidt, 2022). For instance, AI can optimize agricultural practices and enhance predictive analytics, while blockchain can provide traceability and transparency in food sourcing (Rui & Sundram, 2024). The combination of these technologies can help mitigate the adverse effects of climate change on food availability, ensuring that military operations are not hindered by supply chain disruptions (Riaz et., 2023).

Resilience in food supply chains is a critical focus area, particularly in unstable environments. Emerging research clusters emphasize food waste management, blockchain integration, and sustainable supply chains as vital components for maintaining food security (Lwesya & Achanta, 2022). The integration of IoT and blockchain technologies can enhance traceability and accountability within food supply chains, thereby improving overall efficiency (Hasan et al., 2023). Additionally, the adoption of these technologies can facilitate better inventory management and reduce food waste, which is particularly important in military operations where resources are often limited (Opasvitayarux et al., 2022). The ability to monitor environmental conditions and track food products in real-time can significantly enhance the resilience of food supply chains, ensuring that military personnel have access to safe and nutritious food (Wincewicz-Bosy et al., 2022).

The role of IoT in food supply chains cannot be overstated, as it enables the collection and analysis of vast amounts of data throughout the supply chain process. This data-driven approach allows for more informed decision-making and can lead to significant improvements in supply chain performance (Kailaku & Djatna, 2022). For example, IoT technologies can be utilized to monitor ambient conditions during food transportation, ensuring that products remain fresh and safe for consumption (Ferrández-Pastor et al., 2022). Additionally, the integration of IoT with blockchain technology can enhance transparency and traceability, providing stakeholders with real-time information about food products from farm to fork (Xu et al., 2024). This level of visibility is crucial in military operations, where the integrity of food supplies can directly impact operational effectiveness (Iftekhar & Cui, 2021).

Moreover, the challenges associated with adopting IoT in food supply chains must be addressed to fully realize its potential. The complexities involved in implementing IoT solutions within the food supply chain can hinder adoption (Aamer et al., 2021). This complexity necessitates a collaborative approach among stakeholders to develop standardized protocols and systems that facilitate the seamless integration of IoT technologies (Sermuksnyte-Alesiuniene et al., 2021). Additionally, the need for robust data management and security measures is paramount, as the reliance on digital technologies increases the risk of data breaches and cyber threats (Wincewicz-Bosy et al., 2022).

The potential of blockchain technology in enhancing food security is also significant. Blockchain can provide a decentralized and tamper-proof record of transactions within the food supply chain, thereby improving traceability and accountability (Kaur et al., 2022). This is particularly important in military contexts, where the assurance of food safety and quality is critical (Rui & Kaliani Sundram, 2024). The integration of blockchain with IoT can further enhance the capabilities of food supply chains by enabling real-time tracking of products and ensuring that all stakeholders have access to accurate and up-to-date information (Riaz et al., 2023). This level of transparency can help build trust among consumers and stakeholders, ultimately leading to more resilient food supply chains (Hasan et al., 2023).

Overall, the intersection of technological innovations and food security is a rapidly evolving field, particularly in the context of military operations. The integration of IoT, AI, and blockchain technologies has the potential to significantly enhance the resilience and efficiency of food supply

chains, ensuring that military personnel have access to safe and nutritious food even in challenging environments. However, addressing the complexities and challenges associated with these technologies is essential for their successful implementation. Continued research and collaboration among stakeholders will be crucial in developing innovative solutions that can effectively address food security challenges in military contexts and beyond.

Bibliometric analysis approach and selection criteria

This study employs bibliometric analysis, a quantitative method used to examine and interpret patterns and trends in scientific publications (Donthu et al., 2021). It provides a comprehensive view of a research domain, facilitating the assessment of literature progression over time and assisting scholars and policymakers in making informed decisions about future research directions and funding priorities (Abdullah, 2023). Bibliometric analysis also helps identify key themes, influential authors, and collaboration networks within the research field (Mohd Sofian et al., 2023).

Data for this analysis was sourced from Scopus and Web of Science (WoS), two widely recognized databases for their extensive coverage and reliable citation analysis capabilities (Abdullah, 2023). The search focused on the relationship between food security technology and military contexts, ensuring that all relevant literature was included. Both databases allow access to a wide range of scholarly work, facilitating thorough analyses and the identification of influential publications (Durán-Sánchez et al., 2020). In addition, citation analysis tools enabled the evaluation of citation patterns and impact metrics, highlighting pivotal publications in the field (Abdullah, 2021).

Search strategy

After identifying the relevant keywords, a search was conducted across both databases Scopus and Web of Science using synonyms to broaden the exploration of related literature. Table 1 outlines the search criteria used. The search, performed in October 2024, targeted titles, abstracts, and keywords. No restrictions were applied in terms of publication date, type, or language to ensure comprehensive data retrieval (Abd Aziz et al., 2022). The final datasets were analyzed using ScientoPy and VOSviewer, tools that provide bibliometric analysis and visualizations (Abdullah, 2023; Majeed & Ainin, 2021).

Table 1. Search strategy for extracting data from the Web of Science and Scopus databases.

Database	Search Terms	Records Retrieved
Scopus	("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")	326
Web of Science	("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")	495

Thematic analysis approach and selection theme

This study applied thematic analysis to explore patterns in food security and technology within military contexts. Thematic analysis was selected for its flexibility and systematic approach in analyzing qualitative data, which is particularly useful in identifying recurring themes in complex or less-explored areas (Braun & Clarke, 2019). This method enabled in-depth insights into how these technologies are applied in military environments. Specifically, the study followed Braun and

Clarke's (2006) six-phase approach, with adaptations to fit the research context, ensuring a structured and comprehensive analysis:

1. Familiarization with the Data
The researchers immersed themselves in the data through repeated reading to identify initial patterns (Campbell et al., 2021).

2.Generating Initial Codes
Key features of the data were systematically coded to organize relevant sections and highlight significant aspects (Byrne, 2021).

3. Searching for Themes
The initial codes were grouped into broader themes that reflected significant patterns across the dataset (Byrne, 2021).

4. Reviewing Themes
Themes were reviewed and refined to ensure they were coherent and aligned with the research objectives (Hole, 2023).

5. Defining and Naming Themes
Each theme was clearly defined and named to capture its core meaning and relevance to the study (Byrne, 2021).

6. Producing the Final Report
The final report linked the themes to the research questions, with supporting data extracts providing context and evidence (Paoli, 2023). This structured approach allowed the study to uncover significant insights into food security technologies in military contexts, ensuring the findings were deeply grounded in the data and aligned with the research goals.

RESULTS

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 (2006) a well-established six-step framework. This method has been adapted in recent studies (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.

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.

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.

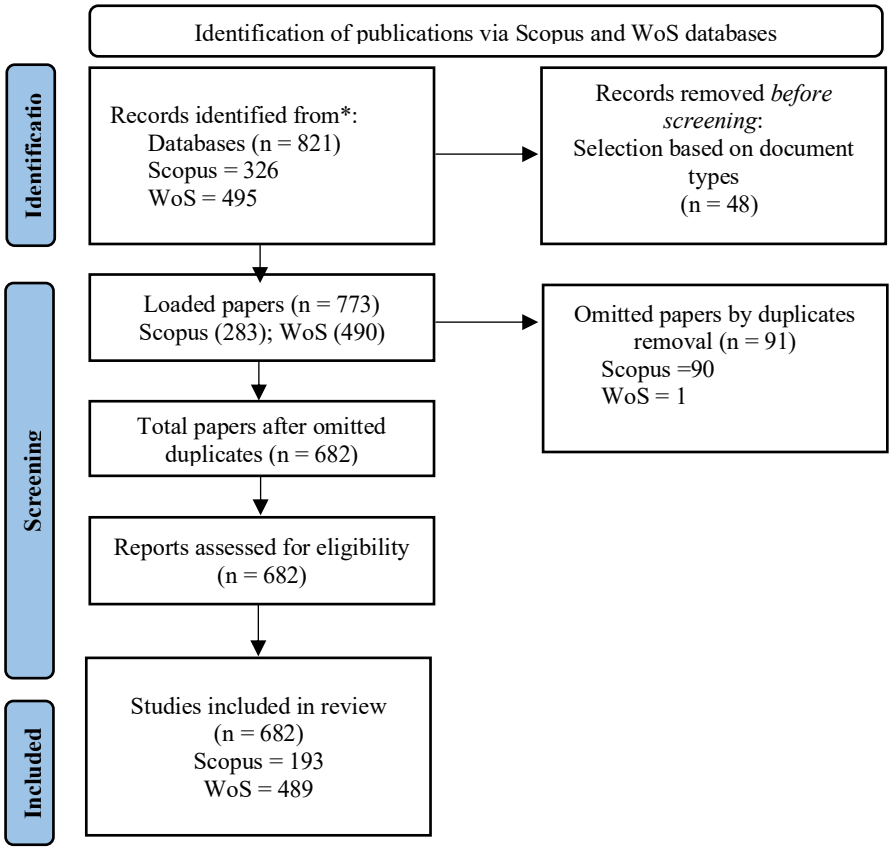

Diagram 1. Flow diagram of searches of databases and registers.

Figure 1 illustrates the structure of the dataset combination and duplicates removal. It demonstrates the importance of carefully curating data from multiple databases to avoid redundancy and enhance the reliability of the findings. The results, post-processing, offer a robust foundation for the subsequent bibliometric analysis.

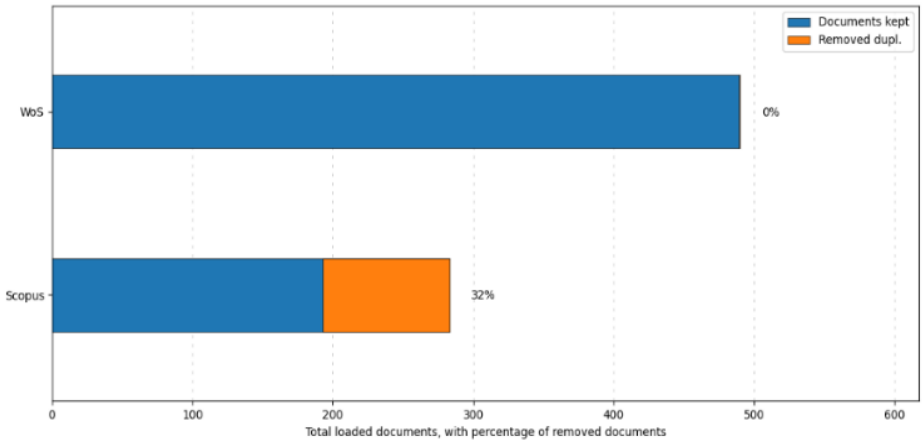

Figure 1: Data combination and duplicates removal.

The evolution of publications

The chart in Figure 2 shows the number of documents published per year in two databases, Web of Science (WoS) and Scopus, from around 1970 to 2024. The data is visualized with blue circles representing WoS and orange triangles representing Scopus. The y-axis shows the number of documents published, and the x-axis represents the publication years. This graph offers a comparative look at the growth in the volume of documents indexed by both databases over time.

From the graph, both WoS and Scopus had minimal publication activity before the early 2000s. Between 1970 and 2000, the number of documents remained low, with small fluctuations in both databases. Starting in the early 2000s, there is a notable upward trend in publications, particularly in WoS. The number of documents indexed by WoS increases steadily, peaking around 2021 with over 40 documents, while Scopus shows a slower but steady increase, with noticeable peaks around 2022.

The most recent years (2022-2024) show a significant convergence in document counts between WoS and Scopus, with both databases experiencing growth. While WoS generally indexes more documents overall, the gap between WoS and Scopus narrows considerably from 2020 onward. This trend could indicate increasing reliance on both databases in recent academic and research circles. The sharp rise in publications in both databases suggests that these years were pivotal, possibly due to expanding research initiatives or global developments such as advancements in technology or increased research output during the COVID-19 pandemic.

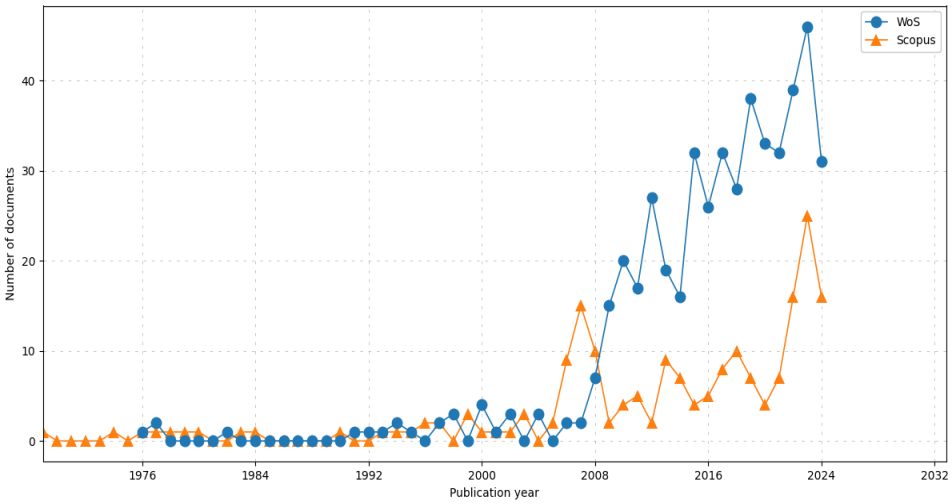

Figure 2. Publication growth.

Productive source titles

Figure 3 and Figure 4 highlight 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 by optimizing agricultural practices and predicting food shortages.

The co-occurrence map further 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 be used to track agricultural conditions through satellite imagery, while machine learning algorithms analyze patterns to predict food shortages and enhance the

efficiency of food distribution systems. Biosensors contribute to ensuring food safety by detecting contaminants and monitoring the quality of food products. The increasing 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 map shows connections between "food security," "war," and "military," suggesting that food supplies are strategic resources in conflict zones. Controlling food availability can influence the outcomes of military operations, and food insecurity often leads to instability and conflict. Although there are no recent publications specifically focusing 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, helping predict food shortages and manage resources in crisis areas. Thus, the two visualizations together reveal the complex and integrated relationship between food security, technology, and military strategy in today's world.

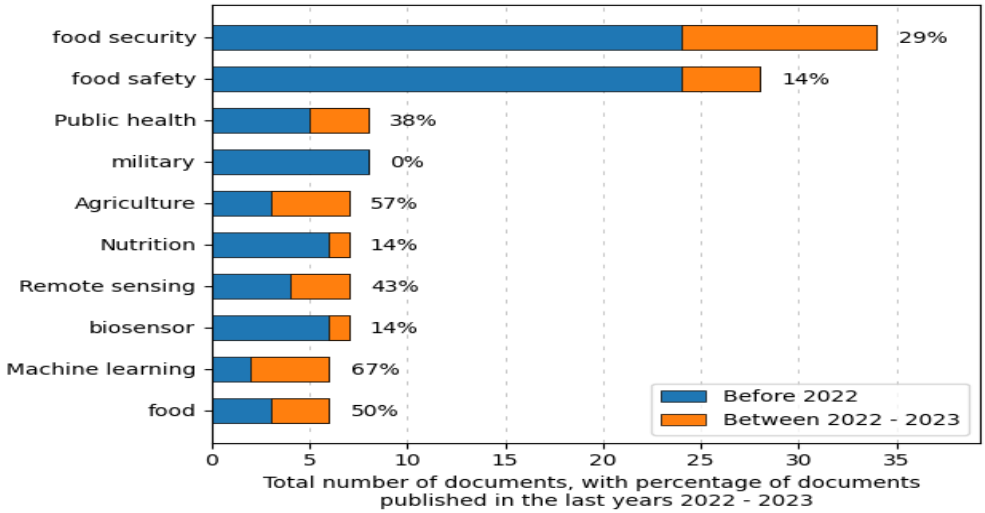

Figure 3. Productive source titles.

Figure 4. Co-occurrence of authors' keywords.

Productive countries

Figure 5 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.

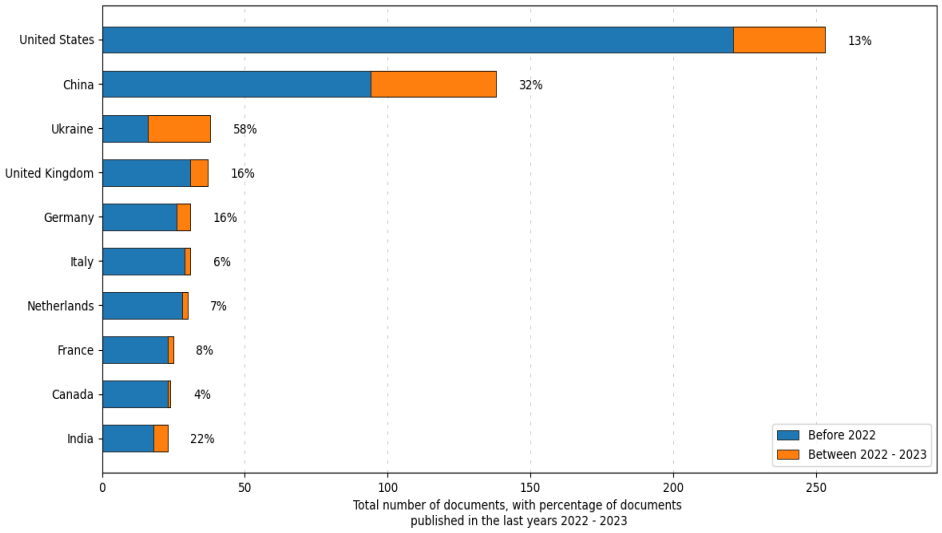

Figure 5. Co-authorship network by countries.

The United States clearly 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.

The most frequently explored subject

Figure 6 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 like Food Science & Technology, Chemistry, Engineering, Environmental Sciences & Ecology, Materials Science, and more. 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.

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. This suggests a broadening interest or the emergence of new interdisciplinary studies in this area. 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 & 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 & 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.

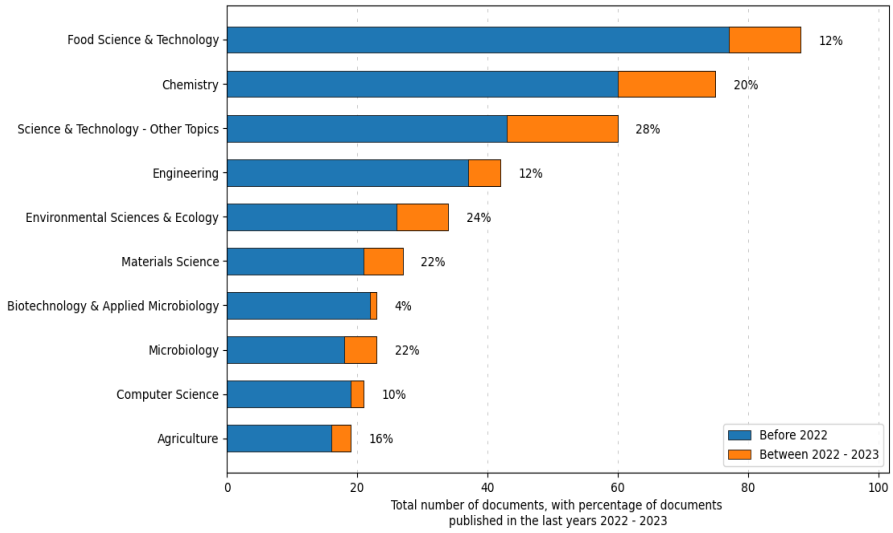

Figure 6. The top ten authors' keywords.

Figure 7 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 Chinese Academy of Sciences, Third Military Medical University, US FDA, MIT, University of Maryland, Michigan State University, University of Cambridge, and others. 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 Sciences and Third Military Medical University 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 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 and Shanghai Jiao Tong University, have also shown considerable recent publication growth, with 21% and 17%, respectively.

On the other hand, institutions like MIT and the US FDA 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, Colorado, and Cambridge 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.

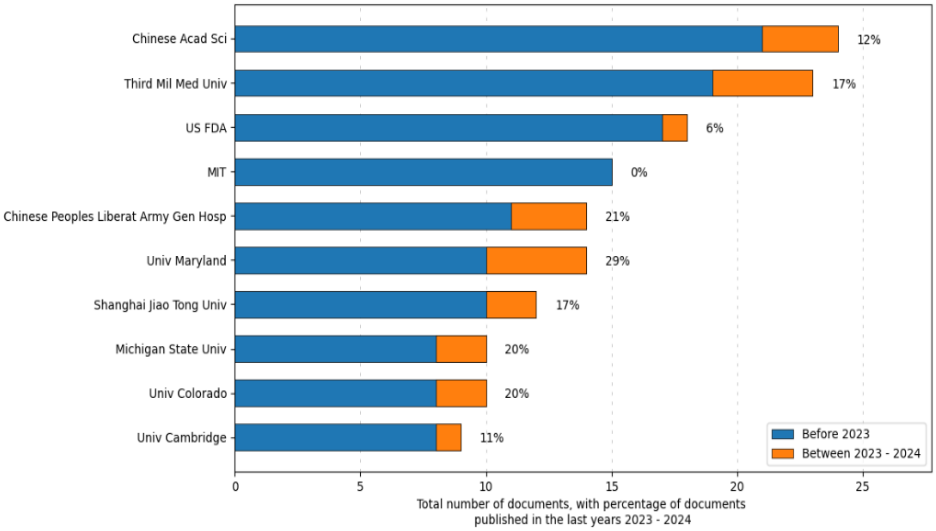

Figure 7. Institution bar trends graph.

Thematic analysis results

Figure 9 illustrates the distribution of research papers across four key themes related to food security and technology in the military. Each slice of the chart is proportionate to the number of papers within each theme, providing a visual representation of the areas that have garnered the most attention from researchers.

1. *Global Food Security and Military Preparedness (621 papers)*

This theme dominates the pie chart, representing most of the papers. The high number indicates a strong focus on ensuring food security as an integral part of military preparedness. Researchers in this area are likely addressing how military operations and strategies intersect with global food supply issues, including logistical challenges in ensuring consistent, nutritious, and safe food for personnel across diverse environments and crisis situations. The sheer size of this slice underscores the importance of global food security in maintaining military readiness and stability.

2. *Environmental Impact of Military Food Systems (19 papers)*

Though significantly smaller, this segment represents the attention being given to the Environmental Impact of Military Food Systems. With 19 papers, this theme highlights growing concern about the sustainability of food practices within military operations. Research in this area likely examines how the military can reduce its ecological footprint in areas such as food waste, supply chain emissions, and sustainable food sourcing, reflecting an evolving awareness of the need for environmentally responsible practices even in highly controlled military settings.

3. *Veterinary and Animal-Based Food Security in Military Operations (16 papers)*

With 16 papers, this theme represents a specialized area of research, focusing on the role of veterinary sciences and the security of animal-based food sources in military contexts. This includes ensuring the health and safety of animals that might be used for food production or other operational purposes in military settings. Though a smaller slice of the pie, this research remains critical for understanding how animal health and food security intersect, especially during deployments in rural or isolated environments where traditional food supplies might be scarce.

4. *Military Dietary Nutrition Systems (1 paper)*

The smallest slice of the chart, representing just one paper, is devoted to Military Dietary Nutrition Systems. This suggests that while military nutrition is essential for operational readiness, it may not receive as much research attention compared to broader food security issues. The lone paper in this category likely deals with the design and development of specialized dietary systems to meet the unique nutritional needs of military personnel, particularly in high-stress or physically demanding scenarios.

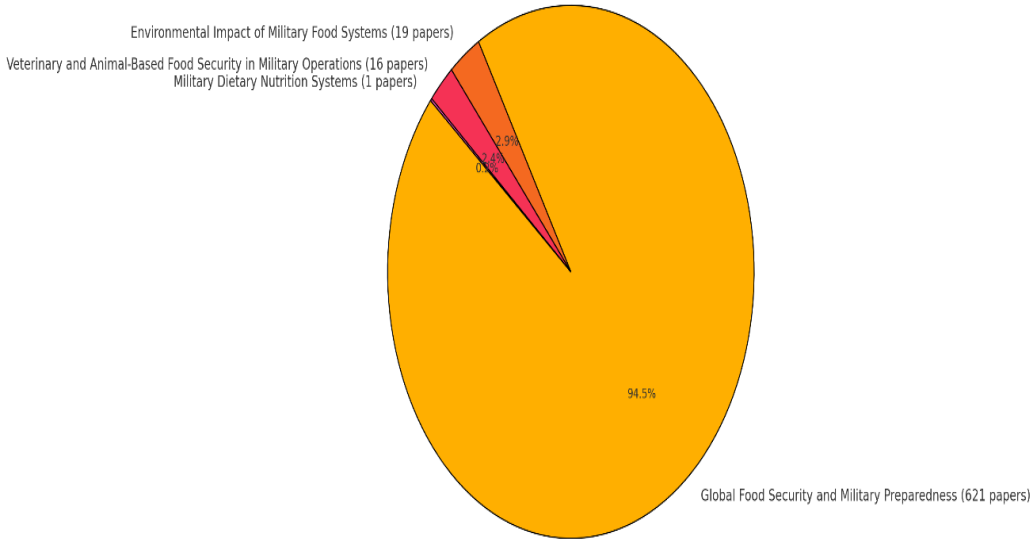

Figure 9. Thematic analysis of food security and technology in military.

DISCUSSION

The growing body of literature from 2019 to 2024 clearly illustrates the increasing importance of food security in military contexts, particularly as global geopolitical tensions, armed conflicts, and environmental crises exert pressure on supply chains. This period has seen an intensified scholarly focus on how technological innovations can enhance the resilience, transparency, and sustainability of food systems that are critical to military operations. The Ukraine conflict and the COVID-19 pandemic have exposed vulnerabilities in existing food supply chains, emphasizing the urgent need for adaptable and secure food provisioning mechanisms (Wincewicz-Bosy et al., 2022).

The impact of armed conflicts on food security is profound and multifaceted. (Halmaghi et al., 2023) reveal that war zones suffer from disrupted agricultural production, destroyed infrastructure, and hampered distribution networks, all of which exacerbate food insecurity both locally and globally. This destabilization jeopardizes the health and operational readiness of military personnel who depend on reliable food sources. Such conflicts also induce ripple effects through global markets, affecting food availability far beyond the immediate zone of conflict. Thus, addressing food security within military settings requires an integrated approach that accounts for both localized supply chain disruptions and broader systemic risks.

Parallel to these challenges is the surge in research focused on technological solutions to mitigate food insecurity. (Namany et al., 2019) highlight the critical role of integrated systems such as the Energy-Water-Food Nexus in optimizing resource allocation amidst climatic and economic uncertainties. This holistic approach is especially relevant in military contexts where resource efficiency can directly impact mission success. The emergence of advanced technologies IoT, blockchain, artificial intelligence (AI), and big data analytics provides novel pathways to enhance food system resilience through real-time monitoring, predictive analytics, and transparent data management (Ruan & Chen, 2023; Kaur et al., 2022).

The rise of IoT in food security reflects its potential to revolutionize supply chain monitoring. By enabling real-time data collection on environmental parameters (e.g., temperature, humidity) and product status, IoT facilitates proactive interventions that prevent spoilage and contamination (Ferrández-Pastor et al., 2022). When integrated with blockchain technology, IoT-driven data becomes immutable and transparent, building trust among stakeholders and ensuring accountability across complex supply networks (Xu et al., 2024). This is particularly vital in military operations where food integrity directly influences soldier health and mission effectiveness (Iftekhar

& Cui, 2021). For instance, blockchain-enabled traceability systems have been shown to reduce fraud and improve recall efficiency, key concerns in food safety management (Hasan et al., 2023).

Artificial intelligence further complements these technologies by providing predictive insights that optimize supply chain decisions. AI-driven analytics can forecast demand fluctuations, detect anomalies, and recommend adaptive strategies to circumvent disruptions caused by environmental variability or geopolitical instability (Martinho et al., 2022; Riaz et al., 2023). This capability is crucial in military logistics, where timely and accurate supply chain adjustments can mean the difference between operational success and failure. Moreover, AI's role in automating routine monitoring tasks reduces human error and increases efficiency in high-pressure military environments (Wamba et al., 2019).

The geopolitical landscape has also influenced the direction of food security research, with countries like the United States and China leading in volume and impact of scholarly output (Ivanov & Yudina, 2023). Ukraine's research surge, motivated by ongoing conflict, underscores the intersection of national security and food system stability. These trends reflect a broader understanding that food security is both a humanitarian concern and a strategic asset influencing military preparedness and geopolitical stability. As Mastos and Gotzamani (2022) emphasize, sustainable supply chain management must incorporate resilience-building strategies that account for environmental, social, and political variables in military food systems.

Sustainability is emerging as a critical consideration in military food security, highlighted by the smaller but growing body of research addressing the environmental impact of military food systems. While operational demands often prioritize efficiency and reliability, the ecological footprint of military food procurement and waste management cannot be ignored (Demianiuk et al., 2022). Innovative solutions are being explored to reduce emissions, minimize waste, and integrate sustainable sourcing practices that align with broader military sustainability goals. For example, the adoption of circular economy principles and the use of biodegradable packaging are gaining attention within military food logistics (Lwesya & Achanta, 2022).

Despite the evident benefits, the adoption of IoT and blockchain technologies faces several challenges. The complexity of integrating these technologies into existing military supply chains requires collaborative efforts to develop standardized protocols and interoperable platforms (Aamer et al., 2021). Security concerns are paramount, as digital systems are vulnerable to cyber-attacks, data breaches, and misinformation, all of which can compromise food supply chain integrity and soldier safety (Wincewicz-Bosy et al., 2022). Robust cybersecurity frameworks, coupled with continuous monitoring and adaptive defense mechanisms, are essential to safeguard these technological ecosystems (Riaz et al., 2023).

Moreover, the need for capacity building and training within military and food system personnel is critical for successful technological implementation. Effective use of AI, IoT, and blockchain requires skilled operators who understand both the technological and logistical aspects of food supply management in military contexts (Opasvitayarux et al., 2022). Research indicates that resistance to change, lack of infrastructure, and limited interoperability can impede adoption, suggesting that organizational change management strategies must accompany technological upgrades (Sermuksnyte-Alesiuniene et al., 2021).

A bibliometric lens reveals the evolving research focus from general food security concerns towards technologically driven solutions. (Ansari et al., 2023) demonstrate that digital transformation of food supply chains, via AI and blockchain, enhances resilience by improving transparency, accountability, and adaptive capacity. Xie et al. (2021) further illustrates how interdisciplinary collaboration enriches understanding of complex food security challenges by linking environmental science, technology, and social policy, particularly relevant to military applications.

Looking ahead, several research avenues warrant attention. First, comparative studies across regions and military contexts could reveal contextual factors influencing technology effectiveness and adoption (Wan & Peng, 2024). Mixed methods approach integrating qualitative insights with bibliometric data would deepen understanding of barriers and facilitators to technological integration Second, developing scalable, modular, and secure digital food supply frameworks tailored to military operational demands is vital. These frameworks should prioritize

flexibility to operate under diverse conflict and disaster scenarios while ensuring data integrity and user accessibility. Third, exploring the socio-political dimensions of food security technology adoption in military settings remains underexplored. Understanding how trust, governance structures, and ethical considerations shape technology acceptance can inform more inclusive and effective implementation strategies (Dos Anjos & De Almeida, 2023). Finally, advancing sustainable military food systems by integrating green technologies and circular supply chain principles aligns with growing environmental imperatives and military strategic goals (Davis et al., 2020).

Overall, the period from 2019 to 2024 has been marked by substantial growth in research at the nexus of food security, technology, and military operations. This trend reflects heightened global awareness of the vulnerabilities in food systems exposed by pandemics and geopolitical conflicts. Technological innovations, notably IoT, AI, and blockchain, have emerged as transformative tools for enhancing supply chain resilience, transparency, and sustainability in military contexts. However, realizing their full potential requires addressing technical, organizational, and security challenges through collaborative, interdisciplinary approaches. Continued research that embraces mixed methods and cross-sector partnerships will be essential for developing robust, adaptive, and sustainable food security systems that safeguard military operational readiness in an increasingly uncertain world.

CONCLUSION

This study comprehensively examined the dynamic intersection of food security, technological innovation, and military operations through both bibliometric and thematic analyses, revealing crucial trends from 2019 to 2024 influenced by global crises such as the COVID-19 pandemic and geopolitical conflicts like the Ukraine war. The bibliometric findings underscore the leadership of countries such as the United States and China in research output, driven by emerging technologies including the Internet of Things (IoT), artificial intelligence (AI), and blockchain, which are pivotal in enhancing the resilience, transparency, and efficiency of military food supply chains. The thematic analysis identified four critical domains: global food security and military preparedness, environmental impacts of military food systems, veterinary and animal-based food security, and military dietary nutrition, with the integration of global food security into military preparedness as the predominant focus. While the environmental and nutritional dimensions remain less explored, they represent essential areas for future inquiry. Despite the promise of technology-driven solutions, challenges persist in technology adoption, cybersecurity, infrastructure integration, and workforce capacity, necessitating interdisciplinary collaboration and innovative policy frameworks. Future research should prioritize the development of adaptable, secure, and sustainable food security frameworks tailored to diverse military contexts while exploring socio-political and environmental dimensions. Ultimately, these insights provide valuable guidance for policymakers, military planners, and researchers to strengthen the resilience and sustainability of military food systems amid an increasingly complex and uncertain global landscape.

ACKNOWLEDGEMENTS

The authors wish to extend their sincere appreciation to all participants who generously contributed to this study. Our profound gratitude goes to the Faculty of Hotel and Tourism and Management Universiti Teknologi MARA, Pulau Pinang Branch, Malaysia and School of Business Management, UUM College of Business, Universiti Utara Malaysia, Sintok Kedah, Malaysia for their invaluable resources and unwavering support. Special recognition is reserved for our dedicated team members, as well as our beloved family and friends; your unwavering contributions and encouragement have been truly invaluable. Thank you.

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS' CONTRIBUTIONS

Mohamad Azli Razali, Elias Md Radzi, Farina Nozakiah Tazijan, Hussin Khan Rahmatullah Khan, Norrina Din, Khairul Hidayat Rezo and Noorliza Zainol contributed equally to the conception and planning of the research. They also participated in the data collection, analysis, and interpretation of the results. Additionally, all authors provided critical feedback and helped shape the research, analysis, and manuscript. Mohamad Azli bin Razali took the lead in writing the manuscript.

REFERENCES

Aamer, A. M., Al-Awlaqi, M. A., Affia, I., Arumsari, S., & Mandahawi, N. (2021). The internet of things in the food supply chain: adoption challenges. *Benchmarking: An International Journal*, *28*(8), 2521–2541. https://doi.org/10.1108/BIJ-07-2020-0371

Abd Aziz, F. S., Abdullah, K. H., Harith, S. H., & Sofyan, D. (2022). Trends and evolution of road user behaviour research: A bibliometric review. *International Journal of Information Science and Management*, *20*(3), 69-93.

Abdallah, M. B., Fekete-Farkas, M., & Lakner, Z. (2021). Exploring the link between food security and food price dynamics: A bibliometric analysis. *Agriculture*, 11(3), 263.

Abdullah, K. H. (2021). Mapping of marine safety publications using VOSviewer. *ASM Science Journal*, *16*, 1-9. https://doi.org/10.32802/asmscj.2021.774

Abdullah, K. H. (2023). Time flies, waste piles: A bibliometric analysis of solid waste management research. *Ecocycles*, *9*(2), 59-70. https://doi.org/10.19040/ecocycles.v9i2.310

Abdullah, K. H., & Abd Aziz, F. S. (2021). Mapping of laboratory safety research: a bibliometric review. *Malaysian Journal of Public Health Medicine*, *21*(1), 303-310. https://doi.org/10.37268/mjphm/vol.21/no.1/art.864

Ansari, M. H., Srivastava, P., Alrasheedi, M., Sharma, S., Gupta, R., Samant, S., & Ratna, S. (2023). Bibliometric Analysis of Food Supply Chain Transformation using Digital Technology. *2023 International Conference on Computational Intelligence and Knowledge Economy (ICCIKE)*, 376–380. https://doi.org/10.1109/ICCIKE58312.2023.10131782

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, 101 - 77. https://doi.org/10.1191/1478088706qp063oa.

Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, 11(4), 589–597. https://doi.org/10.1080/2159676X.2019.1628806

Byrne, D. (2021). A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality & Quantity, 56*, 1391-1412. https://doi.org/10.1007/s11135-021-01182-y.

Campbell, K., Orr, E., Durepos, P., Nguyen, L., Li, L., Whitmore, C., Gehrke, P., Graham, L., & Jack, S. (2021). Reflexive Thematic Analysis for Applied Qualitative Health Research. *The Qualitative Report*. https://doi.org/10.46743/2160-3715/2021.5010.

Davis, K. F., Downs, S., & Gephart, J. A. (2020). Towards food supply chain resilience to environmental shocks. *Nature Food*, *2*(1), 54–65. https://doi.org/10.1038/s43016-020-00196-3

Demianiuk, O., Humeniuk, I., Levishko, A., Vakulenko, S., & Poltava, O. (2022). Environmental Aspects in The Development of Sustainable Food Systems. *Balanced Nature Using*, *4*, 119–128. https://doi.org/10.33730/2310-4678.4.2022.275863

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of business research*, *133*, 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070

Dos Anjos, S. S. N., & De Almeida, A. N. (2023). Food Security and its Connection with Environmental Economics and Accounting: A Bibliometric Analysis. *Revista de Gestão Social e Ambiental*, *18*(3), 1. https://doi.org/10.24857/rgsa.v18n3-010

Durán-Sánchez, A., Álvarez-García, J., González-Vázquez, E., & Del Río-Rama, M. D. L. C. (2020). Wastewater management: Bibliometric analysis of scientific literature. *Water*, *12*(11), 2963. https://doi.org/10.3390/w12112963

Ferrández-Pastor, F.-J., Mora-Pascual, J., & Díaz-Lajara, D. (2022). Agricultural traceability model based on IoT and Blockchain: Application in industrial hemp production. *Journal of Industrial Information Integration*, *29*, 100381. https://doi.org/10.1016/j.jii.2022.100381

Halmaghi, E.-E., Cîrdei, A., & Metea, I.-G. (2023). Food Security and Armed Conflicts. *Land Forces Academy Review*, *28*(4), 329–337. https://doi.org/10.2478/raft-2023-0039

Hasan, I., Habib, M. M., Mohamed, Z., & Tewari, V. (2023). Integrated Agri-Food Supply Chain Model: An

Application of IoT and Blockchain. *American Journal of Industrial and Business Management*, 13, 29–45. https://doi.org/10.4236/ajibm.2023.132003

Hole, G. (2023). Handle with care: Considerations for using Braun and Clarke's approach to reflexive thematic analysis. *QMiP Bulletin, 36*(1), 12-19. https://doi.org/10.53841/bpsqmip.2023.1.36.12.

Iftekhar, A., & Cui, X. (2021). Blockchain-Based Traceability System That Ensures Food Safety Measures to Protect Consumer Safety and COVID-19 Free Supply Chains. *Foods*, *10*(6), 1289. https://doi.org/10.3390/foods10061289

Ivanov, S., & Yudina, S. (2023). Ensuring national food security. *Ekonomìčnij Vìsnik Dnìprovs'kogo Deržavnogo Tehničnogo Unìversitetu*, *2(5)*, 7–15. https://doi.org/10.31319/2709-2879.2022iss2(5).270417pp7-15

Kailaku, S. I., & Djatna, T. (2022). Traceability and Quality Monitoring Improvement Throughout Carrot Supply Chain with the Implementation of Internet-Of-Things. *IOP Conference Series: Earth and Environmental Science*, *1024*(1), 012079. https://doi.org/10.1088/1755-1315/1024/1/012079

Kaur, A., Singh, G., Kukreja, V., Sharma, S., Singh, S., & Yoon, B. (2022). Adaptation of IoT with Blockchain in Food Supply Chain Management: An Analysis-Based Review in Development, Benefits and Potential Applications. *Sensors*, *22*(21), 8174. https://doi.org/10.3390/s22218174

Lamberty, A., & Kreyenschmidt, J. (2022). Ambient Parameter Monitoring in Fresh Fruit and Vegetable Supply Chains Using Internet of Things-Enabled Sensor and Communication Technology. *Foods*, *11*(12), 1777. https://doi.org/10.3390/foods11121777

Li, J., & Song, W. (2022). Food security review based on bibliometrics from 1991 to 2021. *Foods*, 11(23), 3915.

Lwesya, F., & Achanta, J. (2022). Mapping research trends on food supply chain: A bibliometric analysis. *Journal of Agribusiness in Developing and Emerging Economies*.

Majeed, N., & Ainin, S. (2021). Visualizing the evolution and landscape of socio-economic impact research. *Quality & Quantity: International Journal of Methodology*, 55(2), 637–659. https://doi.org/10.1007/s11135-020-01042-5

Martinho, V., da Silva Cunha, C. A., Pato, M. L., Costa, P. J. L., Sánchez-Carreira, M. d. C., Georgantzís, N., Rodrigues, R., & Coronado, F. (2022). Machine learning and food security: Insights for agricultural spatial planning in the context of Agriculture 4.0. *Applied Sciences*. https://doi.org/10.3390/app122211828.

Mastos, T., & Gotzamani, K. (2022). Sustainable Supply Chain Management in the Food Industry: A Conceptual Model from a Literature Review and a Case Study. *Foods*, *11*(15), 2295. https://doi.org/10.3390/foods11152295

Mohd Sofian, F. N. R., Abdullah, K. H., & Mohd-Sabrun, I. (2023). Research on corporate reputation: A bibliometric review of 43 years (1977− 2020). *International Journal of Information Science and Management (IJISM)*, *21*(2), 31-54.

Namany, S., Themistocleous, K., & Miltiadou, M. (2019). Optimisation of the energy-water-food nexus for food security. *Renewable and Sustainable Energy Reviews*, 112, 269-279.

Ohlan, R., & Ohlan, A. (2022). Scholarly research in food security: A bibliometric analysis of global food security. *Science & Technology Libraries*, 42(2), 119-135.

Opasvitayarux, P., Setamanit, S., Assarut, N., & Visamitanan, K. (2022). Antecedents of IoT adoption in food supply chain quality management: an integrative model. *Journal of International Logistics and Trade*, *20*(3), 135–170. https://doi.org/10.1108/JILT-05-2022-0002

Page, M. J., Moher, D., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., & McKenzie, J. E. (2021). PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. *BMJ*, *372*. https://doi.org/10.1136/bmj.n160

Paoli, S. (2023). Writing user personas with large language models: Testing and evaluation phase. *Social Science Computer Review*. https://doi.org/10.1177/08944393231220483

Rejeb, A., Rejeb, K., Abdollahi, A., Zailani, S., Mohammad, I., & Gobakhloo, M. (2021). Digitalization in food supply chains: A bibliometric review and key-route main path analysis. *Journal of Cleaner Production*, 285, 124678.

Riaz, R., Abrar, S., & Gul, M. J. (2023). *Securing Supply-Chain Network with Blockchain* (pp. 243–258). https://doi.org/10.1007/978-3-031-28076-4_20

Ruan, Y., & Chen, H. (2023). Research on Food Security System Based on Internet of Things Technology under the Background of Big Data. *Advances in Engineering Technology Research*, *4*(1), 345. https://doi.org/10.56028/aetr.4.1.345.2023

Rui, F., & Kaliani Sundram, V. P. (2024). Technological Innovation for Sustainable Supply Chain Management in the Food Industry. *Information Management and Business Review*, *16*(3S(I)a), 892–903. https://doi.org/10.22610/imbr.v16i3S(I)a.4173

Ruiz-Rosero, J., Ramírez-González, G., & Viveros-Delgado, J. (2019). Software survey: ScientoPy, a

scientometric tool for topics trend analysis in scientific publications. *Scientometrics*, *121*(2), 1165-1188. https://doi.org/10.1007/s11192-019-03213-w

Sermuksnyte-Alesiuniene, K., Simanaviciene, Z., Bickauske, D., Mosiiuk, S., & Belova, I. (2021). Increasing the effectiveness of food supply chain logistics through digital transformation. *Independent Journal of Management & Production*, *12*(6), s677–s701. https://doi.org/10.14807/ijmp.v12i6.1748

Toromade, A., Soyombo, D., Kupa, E., & Ijomah, T. (2024). Technological innovations in accounting for food supply chain management. *Finance & Accounting Research Journal*. https://doi.org/10.51594/farj.v6i7.1315

Wamba, S. F., Bawack, R., & Carillo, K. D. (2019). The state of artificial intelligence research in the context of national security: Bibliometric analysis and research agenda. In *Proceedings of the 10th International Conference on Information Systems (ICIS)* (pp. 255-266). https://doi.org/10.1007/978-3-030-29374-1_21.

Wan, D., & Peng, L. (2024). Autonomous Vehicle Acceptance in China: TAM-Based Comparison of Civilian and Military Contexts. *World Electric Vehicle Journal*, *16*(1), 2. https://doi.org/10.3390/wevj16010002

Wincewicz-Bosy, M., Sadowski, A., Wąsowska, K., Galar, Z., & Dymyt, M. (2022). Military Food Supply Chain during the COVID-19 Pandemic. *Sustainability*, *14*(4), 2464. https://doi.org/10.3390/su14042464

Xie, H., Wen, Y., Choi, Y., & Zhang, X. (2021). Global trends on food security research: A bibliometric analysis. *Land*, 10(2), 119.

Xu, Y., He, P., Sheng, P., & Li, N. (2024). Design and Implementation of a Blockchain-based Food Traceability System. *2024 4th International Symposium on Computer Technology and Information Science (ISCTIS)*, 347–350. https://doi.org/10.1109/ISCTIS63324.2024.10698760

ABOUT THE AUTHORS

Mohamad Azli bin Razali graduated from Universiti Kebangsaan Malaysia with a Master in Food Science. He holds an honors degree in Food Service Management and a Diploma in Chef Training from Universiti Teknologi MARA. He has been part of the Culinary Department, Faculty of Tourism and Hotel Management, UiTM, for 17 years. His expertise includes basic cookery, commercial cookery, pastry and baking, and food styling. His research interests focus on food acceptance, sensory evaluation, food development, and innovation. He can be reached at his email mohamad080@ uitm.edu.my

Elias Md Radzi, PhD student in Occupational Safety & Health Management, in School of Business Management, College of Business, Universiti Utara Malaysia. His main research activity is in the area of Occupational Safety & Health Management. He has published widely on these subjects in publications such as the Military Technical Courier Journal, Multidisciplinary Reviews Journal, Social Security Management Journal, Spectrum Journal of Social Science, Asian Journal of Research in Education and Social Sciences, International Journal of Research Publication and Reviews; and International Webinar on Social Science and Technology 2024 (IWSST 2024) Proceedings. He can be reached through his email at eliasmdradzi9@gmail.com.

Hussin Khan Rahmatullah Khan is currently serving as a faculty member in the Faculty of Tourism Management at UITM Penang, Malaysia. He holds a B.Sc. in Food Service Management and a Master's degree in Food Sciences. He has developed strong expertise in various areas of the food industry. His research focuses on nutritional aspects, consumer preferences, and emerging trends in the food sector. He can be contacted at email: hussi103@uitm.edu.my

Norrina Din, a distinguished Senior Lecturer in Hospitality and Tourism with a decade of experience, is a prolific scholar. Her research on consumer behavior, food allergy and safety, gastronomy, and education has been featured in magazines, newspapers, articles, and prestigious academic journals, reaching diverse audiences. She has fostered cross-cultural research through MoUs with leading universities in China, Thailand, and Japan. These collaborations bridge theory and practice, enhancing industry standards. Her career is defined by excellence, innovation, and significant contributions to the field of global hospitality and tourism. She can be reached at norrina.din@uitm.edu.my.

Khairul Hidayat bin Rezo, a senior lecturer, holds a Master in Food Science from Universiti Kebangsaan Malaysia, an honors degree in Food Service Management, and a Diploma in Chef Training from Universiti Teknologi MARA. With over 18 years at the Culinary Department, Faculty of Tourism and Hotel Management, UiTM, he brings extensive expertise. Formerly a chef in the hotel industry, his teaching focuses on Malay cuisine, basic cookery, and commercial cookery. His research interests include food acceptance, sensory evaluation, food development, and culinary innovation.khairul077@uitm.edu.my

Noorliza Zainol, is a senior lecturer and an expert in Hospitality and Tourism, focuses on gastronomy, education, consumer behavior, and food hygiene. Her commitment to knowledge dissemination is reflected in her extensive publications across journals, essays, and newspapers, reaching diverse audiences. Beyond academia, she collaborates with industry stakeholders to connect theoretical insights with practical applications. These partnerships provide students and professionals with deeper industry understanding and innovative solutions. Her impactful career demonstrates a dedication to advancing academic excellence and practical advancements in the hospitality and tourism sectors. She can be reached at noorliza690@uitm.edu.my.