
TOWARDS A GREENER NUTRITION AND HEALTHIER WORLD: A BIBLIOMETRIC ANALYSIS OF PLANT-BASED FOODS, EMERGING TECHNOLOGIES, AND THEIR IMPACT ON WOMEN'S HEALTH AND WELL BEING

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Abstract—

The objective of this study is to examine the influence of new technology on research trends concerning plant-based foods and its impacts for world health, has a particular emphasis on women's welfare. A thorough bibliometric study was conducted using data obtained through the Scopus database, concentrating on papers from 1989 to 2024. Initially, 7,111 papers were found, and after using the selection requirements, 4,607 documents were chosen for comprehensive analysis. The research indicates a significant rise in articles about plant-based diets, especially post-2008, associated with progress in data analytics, biotechnology, and artificial intelligence. Prominent themes highlighted include sustainability, health outcomes, and the importance of protein, highlighting the multidisciplinary character of this domain. The research indicates a growing emphasis on gender-specific nutritional factors, especially the impact of plant-based diets on women's health, including maternity nutrition, illness prevention, and general well-being. The results highlight that technology developments have expedited research, resulting in a more profound comprehension of the health advantages of plant-based diets. The findings indicate that stakeholders in the fields of food technology, ecological sustainability, and public health need to work to incorporate these insights into legislation and practices, guaranteeing fair access to nutritional breakthroughs that particularly benefit women. This work enhances the current literature by providing a comprehensive analysis of the correlation between technology improvements and plant-based nutrition research, therefore generating significant insights for scholars, policymakers, and industry professionals.

Keywords: Plant-based diets, Emerging technology, Bibliometric analysis, Women's health, wellbeing, Global health, Sustainability.

I. INTRODUCTION

Plant-based foods have recently surfaced as a promising remedy to concurrently tackle climate change, environmental deterioration, and public health needs, especially with regard to the health and welfare of women. When compared to animal-based food, these diets are linked to lower emissions of greenhouse gases, water consumption, and land usage (Jarmul et al., 2019; Sabaté & Soret, 2014). Transitioning to plant-based diets may help in attaining many Sustainable Development Goals, such as enhanced well-being and health, responsible consumer behaviour, and climate advocacy (Bhatia et al., 2021). Livestock agriculture is a major cause of environmental deterioration, deforestation, and water contamination (Sadeghighazichaki et al., 2020). Furthermore, consumption of plant-based diets has been associated with improved health results, which may possibly decrease the likelihood of cardiovascular illnesses, total death, Obesity and type 2 diabetes are illnesses that disproportionately impact women, in low-resource environments. (Sadeghighazichaki et al., 2020; Bhatia et

al., 2021). Despite obstacles in broad dietary changes, the adoption of plant-based diets offers a sustainable and enduring approach to enhancing human well-being and environmental resilience, while also benefiting women's nutritional security along with avoiding diseases (Sabaté & Soret, 2014). Plant-based foods have substantial ecological and health advantages in comparison to foods with animal-based components. Their potential to decrease the release of greenhouse gases, land usage, and biodiversity loss ranges from 70% to 80% (Aleksandrowicz et al., 2016). However, the effects on water and energy consumption may differ according on the specific dietary preferences (Carey et al., 2023). These dietary patterns are linked to reduced likelihood of developing chronic illnesses such as diabetes, cardiovascular disease, obesity, and some types of cancer, several factors that have specific relevance for women's health (Hemler & Hu, 2019). Plant-based diets are important for women's nutrition since research shows that they may enhance long-term well-being, hormonal balance, and maternal health. (Carey et al., 2023). Plant-based diets have several advantages; nonetheless, meticulous preparation is crucial to fulfil micronutrient requirements for women at distinct life periods, including pregnancy, breastfeeding, and menopause. (Viroli et al., 2023). Global dietary patterns could be transformed to prioritise high-quality, plant-based diets, which could mitigate both environmental and health-related problems, by focused initiatives to meet gender-specific dietary needs (Hemler & Hu, 2019). The worldwide food system is experiencing a substantial metamorphosis propelled by rapidly developing technology and a transition towards plant-derived food products (Hassoun et al., 2022). The convergence of AI, biotechnological fields, biotechnology and digital platforms is fundamentally transforming the processes of food manufacturing, distribution, and consumption (Schroder et al., 2023). Artificial intelligence is facilitating customised dietary planning and improving the creation of plant-based substitutes that closely resemble conventional animal products (Schroder et al., 2023; Tachie et al., 2023). These developments make plant-based diets more accessible, inexpensive, and attractive to a varied population, especially women who decide family nutrition decisions. (Hassoun et al., 2022). By using digital technology, the plant-based food industry is creating innovative market frameworks and ecosystems (Schroder et al., 2023). Despite these limitations, continuous improvements in plant-based food processing technology provide the opportunity for a rapid transition to sustainable and health-focused diets, addressing both environmental concerns and women's nutritional needs (Tachie et al., 2023). The integration of plant-based foods and emerging technologies presents potential solutions to global challenges, including climate change, food security, and gender-specific health inequities (Hassoun et al., 2022). In light of the ongoing climate change catastrophe, environmental degradation, and gender-based health disparities, it is essential to examine the potential of plant-based diets and technology innovations to improve global health outcomes.

A growing corpus of research acknowledges the need to explore the convergence of plant-based nutrition, new technology, and gender health inequities. Bibliometric study offers significant insights into emerging trends, emphasising the relationships among these essential domains. In response to these essential issues, the research questions that follow (RQs) have been formulated:

1. In what ways have new technologies impacted studies pertaining to plant-based diets, women's healthcare, and global well-being?
2. What is the progression of research themes in plant-based nutrition and women's health, especially with sustainability and health outcomes?

Table 1. Research objectives

Research Objectives	Bibliometric Analysis
To analyze the influence of emerging technologies on the development of plant-based food systems and their impact on women's health.	Performance Analysis: Number of publications per year. Science Mapping: Co-word analysis to identify technological trends (co-occurrence).
To analyze the thematic evolution of research in plant-based nutrition and women's health, identifying how sustainability and health outcomes have become central themes over time.	Thematic Evolution

II. LITERATURE REVIEW

Plant-based diets have emerged as a sustainable solution to address environmental and health concerns associated with global food systems. Research indicates that adopting plant-based dietary patterns can significantly reduce greenhouse gas emissions, land use, and water consumption by 20-30% on average, with some studies reporting reductions as high as 70-80% (Aleksandrowicz et al., 2016). These diets are also linked to improved health outcomes, including reduced risk of chronic diseases and all-cause mortality (Aleksandrowicz et al., 2016; Viroli et al., 2023). Plant-based diets are more environmentally sustainable due to their lower resource requirements compared to animal-based diets (Sabaté & Soret, 2014). However, careful planning is necessary to ensure adequate micronutrient intake (Viroli et al., 2023). While the impact on water and energy use may vary depending on food choices, plant-based diets consistently demonstrate lower greenhouse gas emissions, land use, and biodiversity loss compared to standard diets (Carey et al., 2023). Recent studies have highlighted the distinct dietary requirements of women, emphasising the significance of plant-based diets in promoting hormonal equilibrium, reproductive health, and alleviating gender-specific health problems like osteoporosis and iron

insufficiency (Carey et al., 2023). Overall, plant-based diets offer a promising approach to simultaneously address global health and environmental challenges.

Recent research highlights the pivotal role of plant-based diets and technological innovation in addressing global health and sustainability challenges. The shift towards plant-based diets is recognized as a key strategy for reducing diet-related morbidity and mortality while promoting sustainable food systems (Kraak & Aschemann-Witzel, 2024; Hemler & Hu, 2019). Emerging technologies, including artificial intelligence, big data, and biotechnology, are revolutionizing agriculture and food production, enhancing efficiency and sustainability throughout the supply chain (Hassoun et al., 2022; Khan et al., 2021). These innovations contribute to improved nutritional quality, food safety, and sustainable farming practices (Hassoun et al., 2022). Digital health technology and precision nutrition are revolutionising women's healthcare by facilitating personalised dietary recommendations, rectifying nutritional shortages, and enhancing maternal and reproductive health via plant-based nutrition techniques (Hemler & Hu, 2019). The integration of plant-based diets and technological advancements is seen as crucial for achieving the United Nations Sustainable Development Goals, particularly those related to climate action, food security, and health (Kraak & Aschemann-Witzel, 2024). However, successful implementation requires coordinated efforts from governments, businesses, and civil society to promote healthy, equitable, and resilient food systems (Kraak & Aschemann-Witzel, 2024; Khan et al., 2021).

Proposition 1. Emerging technologies profoundly impact study trends concerning plant-based nutrition and women's health.

Emerging technologies are significantly influencing research trends in plant-based diets and global health. The shift towards plant-based diets and digital transformation in food production are identified as megatrends in response to global challenges (Hassoun et al., 2022). New technologies are propelling plant science forward, integrating data across multiple scales to address food sustainability issues (Topp & Jez, 2021). Bibliometric analysis reveals the impact of emerging technologies on global health, emphasizing the importance of research and development in generating evidence for innovation management (Sheng Wu & Bernardo Mariano Junior, 2023). Consumer acceptance of alternative proteins, particularly plant-based foods, is growing, with Industry 4.0 technologies playing a crucial role in enhancing the sensory and nutritional properties of these products (Hassoun et al., 2022). Moreover, innovations in nutrigenomics and artificial intelligence-based nutritional planning are transforming the optimisation of plant-based diets for women's health, targeting issues such as PCOS, (polycystic ovary syndrome), menopause-associated metabolic alterations, and cardiovascular risks (Topp & Jez, 2021). The adoption of digital technologies like artificial intelligence, big data, and 3D printing in smart farms and food factories is improving food system outcomes and facilitating the transition to more sustainable diets (Hassoun et al., 2022).

Proposition 2. The thematic evolution of plant-based nutrition research has increasingly emphasized sustainability and health results due to growing focus on women's well-being.

Recent research on plant-based nutrition has increasingly focused on sustainability and health outcomes. Plant-based diets are recognized as more sustainable, using fewer natural resources and having less environmental impact compared to diets rich in animal products (Sabaté & Soret, 2014).

These diets correlate with reduced chances of chronic illnesses including as obesity, type 2 diabetes, and cardiovascular disease (Hemler & Hu, 2019). Consumer demand for sustainable and healthy food options has driven innovation in plant-based products (Perez-Cueto, 2020). The field of plant-based innovation encompasses various research areas, including agricultural/environmental innovation, food and feed innovation, medical/pharmaceutical research, technology-related innovation, and economic/business aspects (Krzywonos & Piwowar-Sulej, 2022). Research on the effects of plant-based diets on hormone levels, the success of pregnancies, and the treatment of disorders including endometriosis and osteoporosis is particularly abundant in the field of women's health (Krzywonos & Piwowar-Sulej, 2022). Shifting global dietary patterns towards high-quality, plant-based diets could alleviate both health and environmental burdens, potentially improving personal, population, and planetary health (Hemler & Hu, 2019; Sabaté & Soret, 2014).

III. RESEARCH GAP

Existing literature on plant-based diets primarily emphasizes their health benefits and sustainability contributions, yet it largely overlooks the significant role those emerging technologies play in enhancing plant-based food systems. While some studies have recognized the environmental impacts of plant-based nutrition, there remains a substantial gap in understanding how technological innovations—such as artificial intelligence (AI) for precision nutrition, blockchain for food traceability, and the Internet of Things (IoT) for smart farming—are transforming both research and practical applications in this domain. For instance, AI-driven tools are increasingly being utilized to tailor dietary recommendations based on individual health profiles, leveraging complex data analysis to promote personalized nutrition (Raparathi et al., 2022). Moreover, blockchain technology is being integrated with IoT to create optimized food traceability systems, which enhance transparency and accountability within the food supply chain (Khan et al., 2020). Nonetheless, current research has mostly neglected the gendered ramifications of these developments, especially their effects on woman's health and well-being. The unique nutritional requirements of women, particularly during pregnancy, the menopause, and other lifespan stages, need a thorough investigation into how innovative technology might augment plant-based dietary strategies for better health results. Moreover, digital health technologies, such as AI-driven nutrition applications and wearable

technology, provide potential for tackling gender-specific health issues; yet, their utilisation in plant-based nourishment research is still little investigated.

Despite these advancements, there is a noticeable lack of bibliometric studies that systematically map the knowledge structure surrounding plant-based diets in conjunction with these emerging technologies. This absence limits our understanding of how these innovations can contribute to global health and sustainability goals. Addressing this research gap is crucial, as it can provide valuable insights into how technological advancements are shaping the future of sustainable food systems and enhancing women's health outcomes in conjunction with overarching public wellness and environmental goals. By examining the convergence of plant-based dietary habits, technology, and women's health. By exploring the intersection of plant-based nutrition and technology, researchers can better inform global health policies and food system reforms needed to tackle pressing issues like climate change and food insecurity.

IV. METHODOLOGY

Table 2. Methodology

DATA SOURCE
STEP 1-Selection criteria Data collected from Scopus data base, year: 1989- 2024 7,111 documents found
STEP 2-Data retrival and cleaning Search string: (("plant-based diet " OR "plant-based nutrition" OR "plant-based food" OR "vegetarian diet " OR "vegan diet*") AND ("sustainable development goal" OR "sustainable diet*" OR "sustainability" OR "climate change" OR "health outcome" OR "environmental impact" OR "food system*" OR "nutrition") AND("emerging technologies" OR "technological advances" OR "AI" OR "blockchain" OR "IoT" OR "VR" OR "robotics" OR "food technology")AND ("sustainable development goal" OR "sustainable nutrition" OR "sustainability" OR "climate change" OR "health outcome*" OR "environmental impact*" OR "food system*" OR "nutrition")) AND ("women's health" OR "gender health disparities" OR "female nutrition" OR "women's well-being" OR "gender perspective") Language: English Subject area: social sciences, environmental science, agriculture and biological science, Business, Management and Accounting, Economics, Econometrics and Finance, Decision Sciences, Multidisciplinary, Psychology, Arts and Humanities, engineering, health professions, computer science, Gender Studies, Public Health, Medicine, and Life Sciences document type: Article, review publication stage: final Documents without applying filter:7,111 Documents selected for the study after filtering: 4,607
STEP 3- Analysis Performance evaluation, Annual scientific production, Co word analysis, Theme evolution

Bibliometric analysis is a quantitative method that uses statistical and mathematical techniques to study bibliographic data, such as publications, citations, and keywords, in order to measure the output, impact, and evolution of research in a specific field (Öztürk et al., 2024). The main components of a bibliometric analysis involve several key steps that guide researchers in systematically evaluating academic literature within a specific field. Firstly, researchers must define their research objectives, clearly outlining the goals of the analysis. Next, they conduct a literature search and data collection from relevant databases such as Web of Science or Scopus, ensuring they gather a comprehensive dataset of pertinent publications. Following this, data cleaning and preprocessing is essential to refine the dataset by removing duplicates and correcting inaccuracies. Researchers then select appropriate bibliometric techniques based on their objectives, which may include methods like co-citation analysis or bibliographic coupling. The data analysis phase involves applying these techniques to uncover insights and patterns within the literature. Subsequently, the results are visualized using tools like VOSviewer or CiteSpace to facilitate interpretation. Finally, researchers must engage in interpretation and reporting, summarizing their findings and discussing their implications for the field. This structured approach allows for a thorough understanding of the intellectual landscape and trends within the chosen research area (Passas, 2024)

V. RESULTS AND DISCUSSIONS

Performance Analysis

The constant rise in publication over time is evidence of the substantial impact of emerging technologies on the study landscape of plant-based diets, female health and health worldwide. Research activity between 1989 and

really augmenting the investigation of the impact of plant-based nutrition on world health. Technological breakthroughs are significantly advancing studies on the health and nutritional advantages of plant-based diets, especially for women's well-being. This trend underscores how instruments such as artificial intelligence, biotechnology, and food technology are enabling more profound enquiries into the effects of plant-based nutrition on health, sustainability, and gender-specific dietary requirements. The favourable association between technical improvements and research trends substantiates the idea that developing technologies are significantly influencing the study of plant-based nutrition, particularly for global health, sustainability, and women's special health issues.

Thematic Analysis

From 1989 to 2024, the thematic evolution of research on plant-based nutrition has progressively shifted towards sustainability, health outcomes, and women's well-being.

- Early research (1989-2001) primarily focused on "diet" and "food technology," with limited exploration of broader health and sustainability themes. Studies during this phase were largely centered on food composition, processing techniques, and basic nutritional aspects.
- Between 2002 and 2013, there was a noticeable shift towards "human" health, with increasing prominence of terms like "nutrition" and "article," reflecting a growing interest in the physiological effects of plant-based diets. This period marked the beginning of more comprehensive investigations into plant-based nutrition's role in disease prevention, metabolism, and general well-being.
- From 2014 to 2024, research has expanded into more specialized domains such as "chemistry" and "proteins," highlighting an increased focus on food processing techniques, bioavailability, and sustainable production. Additionally, studies have increasingly examined plant-based nutrition through the lens of women's health, addressing critical aspects such as hormonal balance, reproductive health, chronic disease prevention, and nutrient sufficiency for different life stages.

The growing influence of emerging technologies—including artificial intelligence, biotechnology, and food science innovations—has further accelerated the shift in plant-based nutrition research towards sustainability and health outcomes, particularly in the context of women's well-being. This thematic evolution underscores the increasing recognition of plant-based diets not only as a sustainable solution for environmental challenges but also as a key factor in promoting gender-specific health benefits.

The progression of research from 1989 to 2024 clearly reflects a gradual yet definitive transition towards sustainability, health outcomes, and the integration of emerging technologies, with a notable emphasis on women's health.

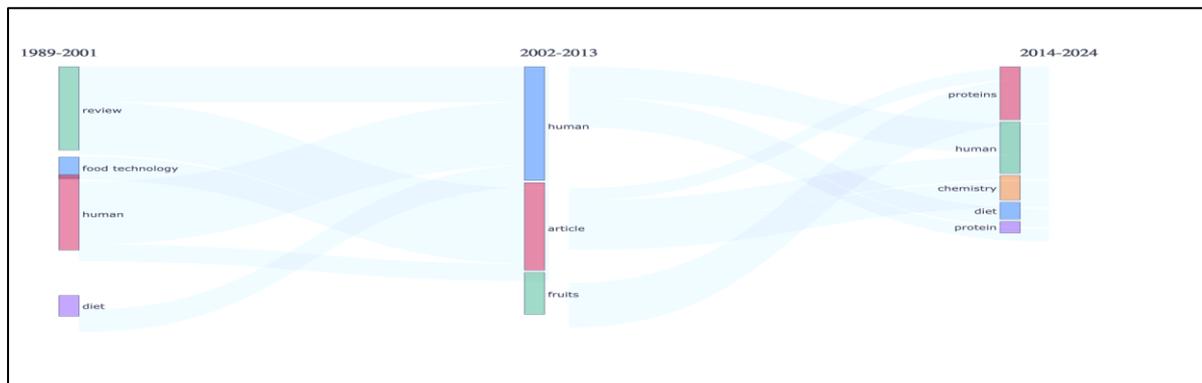


Figure 3: Thematic Evolution

V. DISCUSSION AND CONCLUSION

This bibliometric study provides a comprehensive analysis of the influence of emerging technologies on research advancements in plant-based foods, nutrition, and women's health and well-being. The performance analysis reveals a substantial increase in publications from 2008 onward, reaching a peak in 2023 and 2024. This surge aligns with technological breakthroughs in artificial intelligence (AI), biotechnology, and data analytics, which have enabled researchers to explore the intersection of plant-based diets, sustainability, and health, particularly in the context of women's healthcare.

The co-word analysis identifies five primary research clusters: "non-human," "human," "protein," "antioxidants," and "sustainability."

- The prominence of "protein" as a central theme underscores ongoing discussions about the adequacy of plant-based diets to meet women's unique nutritional needs, particularly in relation to protein intake across different life stages (e.g., pregnancy, lactation, menopause).
- The strong presence of "non-human" suggests a growing shift toward plant-based protein alternatives and lab-grown meat, driven by advancements in food technology and biotechnology, offering sustainable and health-boosting options that may benefit women with dietary restrictions or ethical concerns.

• The dominance of "human" health outcomes highlights the increasing recognition of plant-based foods in addressing global health concerns, including those specific to women's health, such as hormonal balance, reproductive health, heart disease, and chronic disease prevention.

• The focus on "antioxidants" emphasizes the nutritional and wellness benefits of plant-based foods, particularly their role in disease prevention, immune function, and aging, issues that are often central to women's health as they age.

• The prevalence of "sustainability" reinforces the growing acknowledgment of plant-based nutrition as a key solution for both environmental preservation and long-term health improvements, particularly relevant in mitigating health disparities faced by women globally.

This study confirms that emerging technologies have significantly shaped research trends on plant-based diets, sustainability, and health, particularly within the framework of women's well-being. Technological advancements have accelerated scientific exploration and shifted the research focus toward sustainability and health outcomes, ensuring that women's health becomes a more prominent area of study within this context. As AI-driven food innovations, precision nutrition, and biotechnology continue to evolve, plant-based food systems are expected to witness further transformations that support healthier and more sustainable dietary practices worldwide. In addressing the dual challenge of promoting public health and mitigating environmental impact through sustainable food systems, this study underscores the critical need for continued research. The findings from the bibliometric and co-word analyses validate this need:

• The increase in research publications on plant-based diets, largely influenced by technological advancements, substantiates Proposition 1, particularly in relation to women's health and nutrition.

• The thematic evolution analysis confirms a distinct shift toward health outcomes and sustainability, reaffirming Proposition 2 as a dominant focus in contemporary research, emphasizing women's health as a key area of investigation in sustainable food systems.

Theoretical Implications

Recent research underscores the growing importance of plant-based diets and emerging technologies in addressing global health challenges, particularly in the context of women's well-being. Studies emphasize how plant-based innovations, biotechnology, and digital technologies enhance sustainability, food security, and nutritional quality (Hassoun et al., 2022; Krzywonos & Piwowar-Sulej, 2022). Plant-based diets are widely recognized for their sustainability benefits, lower environmental impact, and reduced resource consumption compared to animal-based diets (Sabaté & Soret, 2014). This shift is considered essential for feeding the growing global population while addressing gender-specific health concerns, such as hormonal balance, reproductive health, and disease prevention (Kraak & Aschemann-Witzel, 2024). Research highlights key areas such as agricultural innovation, plant-based food development, medical applications, and economic factors influencing plant-based diets (Krzywonos & Piwowar-Sulej, 2022). To foster sustainable food systems, experts advocate for collaborative efforts among governments, businesses, and civil society to promote plant-rich diets while ensuring gender-inclusive nutrition policies (Kraak & Aschemann-Witzel, 2024).

Managerial Implications

Recent bibliometric analyses reveal a rising emphasis on sustainability, plant-based innovations, and gender-specific nutrition needs in the food industry. Research trends indicate a shift toward sustainable food system management, life cycle assessments, and health-driven dietary transitions (Nicolás & Geldres-Weiss, 2023). Technological advancements in food science, including AI-driven nutritional optimization, biotechnology, and plant protein enhancement, have led to new product development opportunities (Castillo-Vergara et al., 2021). The integration of plant-based nutrition into healthcare and dietary recommendations for women is becoming a major focus, with five key research areas identified:

- Agricultural/environmental advancements supporting plant-based nutrition.
- Food and feed innovations improving plant-based food availability.
- Medical and pharmaceutical applications related to disease prevention and women's health.
- Technology-driven innovations improving food processing and nutritional optimization.
- Economic and business considerations shaping the plant-based food market (Krzywonos & Piwowar-Sulej, 2022).

The growing consumer demand for sustainable, clean-label, and ethically produced plant-based foods is a driving force behind industry innovation. However, challenges such as nutritional adequacy for women, bioavailability of plant-based nutrients, flavor development, and regulatory gaps remain critical concerns (Tachie et al., 2023). Investing in plant-based food development tailored to women's health needs could enhance dietary accessibility, sustainability, and long-term well-being.

Study Contributions

This study offers a comprehensive bibliometric analysis of research trends in plant-based nutrition, emerging technologies, and their impact on women's health. By identifying key thematic areas such as sustainability, health outcomes, and food technologies, the study provides valuable insights into how technological advancements influence plant-based food systems and gender-specific health considerations.

1. Academic Community

- This study presents a detailed examination of plant-based nutrition, women's health, and technological advancements.
 - It identifies critical research gaps, emerging trends, and future research directions in gender-sensitive nutrition and sustainable food systems.
2. Policymakers
 - Findings support evidence-based policymaking to promote plant-based diets in women's healthcare frameworks.
 - Regional research trends can guide localized interventions, ensuring equitable access to sustainable nutrition.
 3. Food Processing Professionals
 - Insights from this study can help develop plant-based products enriched with essential nutrients for women, such as iron, calcium, and vitamin B12.
 - Understanding market trends and sustainability considerations can aid in creating competitive plant-based food products.
 4. Healthcare Practitioners
 - The study highlights the role of plant-based diets in addressing women's health challenges, including reproductive health, metabolic disorders, and longevity.
 - Healthcare professionals can leverage these findings to recommend balanced plant-based diets that cater to women's nutritional needs.
 5. Environmental Organizations
 - This research reinforces the sustainability benefits of plant-based diets and their potential to mitigate environmental impact.
 - Organizations advocating for climate-friendly dietary shifts can use these findings to promote gender-inclusive sustainable food policies.

Limitations and Scope for Future Research

This study has certain limitations, including potential biases in literature selection, as bibliometric analysis primarily relies on published sources, potentially overlooking emerging grey literature and qualitative insights. Additionally, the methodology may not fully capture the nuanced effects of emerging technologies on plant-based diets, particularly regarding gender-specific nutritional challenges.

Future research directions include:

- Exploring qualitative dimensions of plant-based nutrition, particularly consumer perceptions, cultural acceptance, and behavioral shifts toward plant-based diets in women's health.
- Conducting longitudinal studies to track the evolution of plant-based nutrition research, particularly its intersection with gender, health, and sustainability.
- Expanding geographical focus to understand regional disparities in plant-based nutrition adoption and the influence of local socio-economic conditions.

By addressing these research gaps, future studies can provide a more holistic understanding of how plant-based food systems and emerging technologies contribute to sustainable health outcomes, particularly for women.

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