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Global trends in the application of artificial intelligence in sensory science: A bibliometric analysis in the context of food science

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Abstract

The growing demand for more personalized, functional, and sensorially appealing foods has driven the adoption of computational approaches in the food sector. In this context, the application of artificial intelligence to sensory science emerges as a promising alternative to automate evaluations, predict consumer preferences, and enhance innovation in food products. The aim of this study was to map the international scientific output on the topic through a bibliometric analysis of 735 articles indexed in the Web of Science database between 1991 and 2025. The Bibliometrix (R) and VOSviewer software tools were used to extract indicators of productivity, impact, collaboration, and thematic structure. The results show a significant growth in publications since 2016, with a strong concentration in the last 5 years. China, India, and Brazil rank among the most productive countries, with notable contributions from authors based in Australia and East Asia. The co-occurrence analysis revealed seven thematic clusters, highlighting approaches based on machine learning, neural networks, computer vision, and electronic sensors. This study contributes to the understanding of the field's evolution and provides insights to inform research and development strategies in the food sector.

Keywords: machine learning; data-driven innovation; predictive modeling; neural networks.

Practical Application: Identify global trends in artificial intelligence applied to sensory science in food systems.

1 INTRODUCTION

Food science is a multidisciplinary field that integrates knowledge from chemistry, physics, microbiology, nutrition, and sensory science, with the goal of developing safer, healthier, and more acceptable food products for consumers. Among its subfields, sensory science stands out, as it focuses on the analysis of human perceptions regarding the organoleptic attributes of food, such as taste, aroma, texture, appearance, and sound. To ensure the accuracy and reliability of these evaluations, descriptive methods, trained panelists, and standardized statistical analyses are employed (Damásio & Costell, 2011; Stone & Sidel, 1993).

Despite methodological advances, traditional sensory evaluation presents limitations such as response subjectivity, evaluator variability, and high operational costs—factors that hinder the standardization and scalability of results in both academic and industrial contexts (Jayan et al., 2025; Sipos et al., 2021). In this context, the application of artificial intelligence (AI) techniques has shown promise in addressing these challenges by offering solutions capable of automating and enhancing sensory evaluation processes.

AI, as a field of computer science, is dedicated to the development of systems capable of simulating human cognitive functions such as perception, learning, and decision-making (Russell & Norvig, 2013). In the food sector, machine learning algorithms, artificial neural networks, fuzzy logic, and computer vision have been integrated into various stages of production, with applications ranging from quality control and traceability to computer-assisted sensory evaluation (Zatsu et al., 2024). These technologies have proven effective in predictive modeling of sensory preferences, nutritional personalization, and the simulation of human judgments based on large volumes of data, significantly expanding the potential for innovation in the sector (Yang et al., 2025).

Although the application of AI to sensory science has progressed significantly in recent years, the scientific literature on the subject still lacks systematizations that enable a comprehensive understanding of its trajectory, scope, and key contributors. There is a shortage of studies that structurally investigate the configuration of this emerging field—including co-authorship networks, institutional collaborations, predominant thematic areas, and technological trends. In this context, mapping the

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scientific output is essential for identifying development patterns, intellectual connections, and the overall impact of research (Martins, 2013).

Bibliometrics constitutes a well-established and methodologically robust approach for this purpose. It is a branch of information science focused on the quantitative analysis of scientific activity through the measurement of data extracted from academic publications (Mostafa & Máximo, 2003; Rostaing, 1997). This methodology enables the mapping of the structure of scientific output, the measurement of author and institutional productivity, the identification of collaboration networks, and the monitoring of the evolution of specific research areas. Indicators such as publication volume, term co-occurrence, bibliographic coupling, and citation networks allow for empirical and comparable analyses, providing strategic insights for the formulation of research, development, and innovation agendas (Faria, 2001; Saes, 2000; Silva et al., 2011; Spinak, 1998).

Based on this framework, the aim of this study is to conduct a bibliometric analysis of the international scientific output related to the application of AI in sensory science, within the context of food science. The research encompasses the identification of publication patterns, the most cited articles, the most recurrent topics, and the geographical distribution of scientific production. The objective is to provide a structured overview of the field's evolution, contributing to the development of research and innovation strategies aligned with the current demands of the food sector.

1.1 Relevance of the work

The growing demand for more personalized, nutritious, and sensorially appealing foods has driven the food industry to seek technological solutions that enhance the understanding of consumer preferences. In this scenario, the integration of artificial intelligence (AI) into sensory science emerges as an innovative and promising approach capable of optimizing the prediction of consumer acceptance and guiding the development of products aligned with market demands. AI contributes to the automation and standardization of sensory evaluation processes, providing greater accuracy, scalability, and objectivity. This study offers a comprehensive overview of the international scientific output on this thematic interface, identifying emerging trends, research gaps, and the main actors involved. The results presented may support researchers, industry professionals, and policymakers in making more strategic decisions regarding the application of AI techniques in sensory evaluation, product enhancement, and innovation in the food sector.

2 MATERIAL AND METHODS

2.1 Data source and bibliographic search strategy

The bibliographic search was conducted using the Web of Science—Core Collection database, selected for its broad multidisciplinary coverage, rigorous curation, and specific features for bibliometric analysis. This database indexes publications dating back to 1900, including high-impact scientific journals, books, and conference proceedings in the fields of natural sciences, social sciences, arts, and humanities. All records include cited references that are fully indexed and searchable, enabling robust analyses of authorship, institutional affiliation, citation networks, and thematic trends. Among the available tools, citation alerts, analytical reports, and the Analyze Results feature were used in this study to identify patterns of scientific output and collaboration.

Access to the database was obtained through the CAPES Journal Portal (*Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*), which provides institutional access to international scientific information sources and thousands of full-text journals. The search strategy was based on the construction of a query composed of three interrelated thematic categories: sensory science, including terms such as "sensory analysis," "consumer acceptance," and "flavor profile"; AI, with descriptors such as "machine learning," "deep learning," "predictive modeling," and "neural networks"; and food science, with terms such as "food science," "food processing," and "product development."

The terms within each category were combined using the Boolean operator OR, in order to broaden the thematic scope. The three categories, in turn, were integrated using the AND operator, restricting the results to documents that simultaneously addressed all three conceptual axes: sensory science, AI, and food science. The search was conducted on September 1, 2025, and applied to the TS (Topic Search) field, which includes the title, abstract, and keywords of the indexed records.

The time frame considered encompassed the entire indexing period available in the Web of Science. Only original research articles were selected, while reviews, conference proceedings, editorials, technical notes, and other document types not relevant to the scope of the analysis were excluded. After the data refinement and processing stage, the final sample consisted of 735 articles, which were organized for analysis in the subsequent stages of the study, ensuring methodological reliability and the reproducibility of results.

Table 1 schematically presents the search strategy used to construct the analyzed corpus, detailing the conceptual components, the thematic descriptors employed, the Boolean operators applied, and the inclusion and exclusion criteria, as well as the tools used for data access and processing.

2.2 Data processing and analysis

After the data collection stage, the bibliographic records extracted from the Web of Science database were organized using Microsoft Excel, which was employed to perform the initial screening of documents according to the defined inclusion and exclusion criteria. This step also enabled the systematization of bibliographic variables such as publication year, country of origin, authors' institutional affiliation, and keywords, allowing the construction of descriptive charts to visualize the temporal evolution of scientific output and its geographical distribution.

Advanced bibliometric analyses were conducted in the R environment using the Bibliometrix package (version 5.0), which is widely recognized for its robustness in applying productivity, impact, and scientific collaboration metrics. This tool enabled the identification of the most productive authors and countries,

Table 1. Search strategy for the bibliometric analysis of artificial intelligence applications in sensory science and food science.

Component	Search Expression	Observations
Web of Science—Core Collection	–	Covers publications indexed since 1990. Multidisciplinary database with strong curation and advanced analytical tools.
Thematic axes	1. Sensory science: TS=("sensory analysis" OR "sensory evaluation" OR "sensory perception" OR "consumer acceptance" OR "consumer preference" OR "flavor profile" OR "taste analysis" OR "aroma profile" OR "texture perception" OR "organoleptic evaluation") 2. Artificial intelligence: TS=("artificial intelligence" OR "AI" OR "machine learning" OR "ML" OR "deep learning" OR "DL" OR "neural networks" OR "predictive modeling" OR "data mining" OR "data-driven" OR "pattern recognition" OR "random forest" OR "support vector machine" OR "SVM" OR "automated" OR "intelligent system") 3. Food science: TS=("food" OR "food technology" OR "food science" OR "food quality" OR "food industry" OR "food formulation" OR "food innovation" OR "product development" OR "food processing")	Allows scoping of the analysis into three complementary dimensions: methodological, technological, and sectoral.
Combination of descriptors with Boolean operators	Use of OR to expand results within each axis, and AND to restrict the intersection of all three axes. Example: Sensory Science AND Artificial Intelligence AND Food Science.	Ensures specificity in retrieval and alignment with research objectives.
Types of documents selected	Scientific articles indexed in WoS (excluding reviews, editorials, book chapters, conference abstracts, and other non-original research content).	Ensures analysis of content relevant to scientific knowledge production.
Types of documents removed	Excluded 86 documents without abstracts or with unrelated content—final dataset: 735 articles.	Guarantees inclusion of structured metadata.
Platform used for database access	CAPES Journal Portal.	Federated access to national and international scientific content and databases.
Software used for data analysis	Analyze Results (WoS), Microsoft Excel, VOSviewer®, Bibliometrix.	Tools used for performance analysis, co-authorship networks, country mapping, and keyword co-occurrence.

as well as the most cited articles within the analyzed corpus. Additionally, VOSviewer (version 1.6.20) was used to construct graphical visualizations of the field's thematic structure based on co-occurrence maps of terms extracted from titles, abstracts, and keywords. These maps allowed the identification of thematic clusters, revealing consolidated subfields and emerging trends at the interface between AI and sensory science.

3 RESULTS AND DISCUSSION

3.1 Evolution of scientific output and citation impact

Figure 1 presents the evolution of international scientific output on the application of AI in sensory science and food technology, based on the 735 articles retrieved from the Web of Science—Core Collection. Although the first record dates back to 1991, substantial growth in output only became evident from the 2010s onward. Between 1991 and 2010, only 52 articles were published, reflecting the embryonic stage of the field and the limited penetration of digital technologies in the food sector during that period.

In the following 5-year period (2011–2015), a slight increase was observed, with 55 articles published. However, the interval from 2016 to 2020 marked a more pronounced inflection, with 157 publications. This surge is directly related to the maturation of AI applications in experimental areas, particularly predictive and automated approaches aimed at the sensory analysis of food—evidence of an ongoing methodological transformation in the field (Nunes et al., 2023).

The period between 2021 and August 2025 concentrated the majority of publications, with 471 articles—an average of over 94 per year. The years 2024 (132 articles) and 2025 (129 articles up to August) represented the highest peaks in the analyzed period, highlighting the consolidation of this topic as an emerging and increasingly valued field in international research centers. The increase in the annual frequency of publications reflects not only greater scientific output but also the growing institutionalization of the theme within research agendas in food science and technology.

In addition to the increase in publication volume, there has been a notable rise in the academic impact of the field, measured

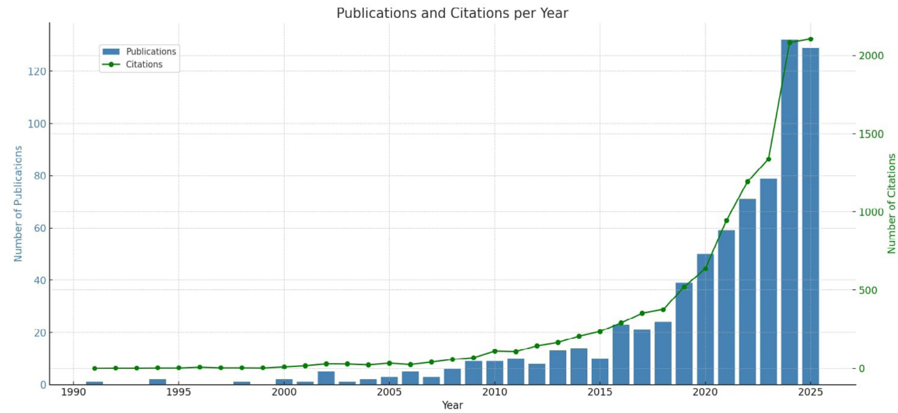

Figure 1. Evolution of the number of scientific publications and citations on artificial intelligence applied to sensory science and food technology between 1991 and 2025.

by the number of accumulated citations. As of August 2025, the 735 analyzed articles had received a total of 11,138 citations. From 1991 to 2010, these articles accumulated only 208 citations, a number that rose to 1,233 between 2011 and 2015. Between 2016 and 2020, there were 2,974 citations. In 2024 and 2025 alone—2,083 and 2,106 citations, respectively—more than 38% of all citations in the period were concentrated, indicating the recent recognition and scientific impact of this research area.

This exponential growth in citations demonstrates the maturation of the field and its methodological and applied relevance. As pointed out by Menezes et al. (2018) and Nielsen and Rios (2000), the use of machine learning algorithms and predictive modeling in sensory science has led to improvements in accuracy, scalability, and standardization, enhancing the ability to estimate sensory attributes based on physicochemical and microbiological data. These advances reinforce the strategic role of AI in modernizing the food production chain, particularly in the development of products that better match consumer preferences.

Recent studies, such as those by Castro et al. (2023) and Pasitka et al. (2023), highlight the transition of sensory science from a predominantly empirical field to a data-driven approach, with a strong interface with computing and food engineering. The integration of electronic sensors, neural networks, and human preference data has enabled the automated simulation of sensory judgments, increasing the potential for innovation and real-world application in the field.

3.1.1 Most cited articles

Figure 2 presents the 10 most cited articles among the 735 analyzed, which together account for 1,695 citations—approximately 15.2% of all 11,122 citations identified. Of the articles considered, 610 received at least one citation, while 125 have not yet been cited. The overall average was 18.23 citations per article, and 172 publications exceeded the threshold of 20 citations. The chart highlights a strong concentration of impact in a small number of articles, which is consistent with citation distribution patterns in emerging fields, such as the application of AI in sensory science and food technology.

Among the most cited articles, the following stand out: Nielsen and Rios (2000), with 303 citations; Çam et al. (2014), with 274; and Lange and Nakamura (2021), with 183. The first two predate the last decade but still exert a strong influence on the current literature, reflecting their foundational relevance. In contrast, the article by Lange and Nakamura (2021) exemplifies recent impact, indicating the rapid assimilation of innovative research in the field. The temporal diversity among the most cited works suggests that the field maintains a dialogue between established foundations and contemporary approaches.

Additionally, the average annual citation rate (indicated by the line in the chart) reveals that more recent articles have achieved higher annual impact rates. This is the case for Pasitka et al. (2023), with 37.33 citations per year, followed by Lange and Nakamura (2021) (36.60) and Mavani et al. (2022) (32.50). These figures suggest a growing interest and visibility for recent publications, likely driven by the expansion of research networks and the exponential growth of the topic in recent years. This pattern reinforces the importance of closely monitoring recent scientific output—not only in terms of volume but also in its pace of dissemination.

3.2 Concentration of scientific output by country and author

3.2.1 Most productive countries

A total of 89 countries were identified as having publications within the analyzed period, highlighting the broad international dissemination of the topic. However, the output is highly uneven: 17 countries published only one article, 7 contributed two, 15 had three publications, and an even smaller number had intermediate participation. On the other hand, the 10 most productive countries (Figure 3) account for 514 articles, which represents 52.51% of the total 735 publications—revealing a significant concentration of scientific activity in a few nations.

China holds the leading position with 149 articles, reflecting its structured investment in science, technology, and innovation. It is followed by India (69 articles) and Brazil (57), indicating the progress of emerging countries in establishing scientific agendas focused on AI applications in food. The United States and Spain follow closely, with 56 and 37 publications, respectively. Italy and South Korea each contributed 31 articles, while Egypt (30), Iran (28), and Japan (26) complete the ranking of the 10 most

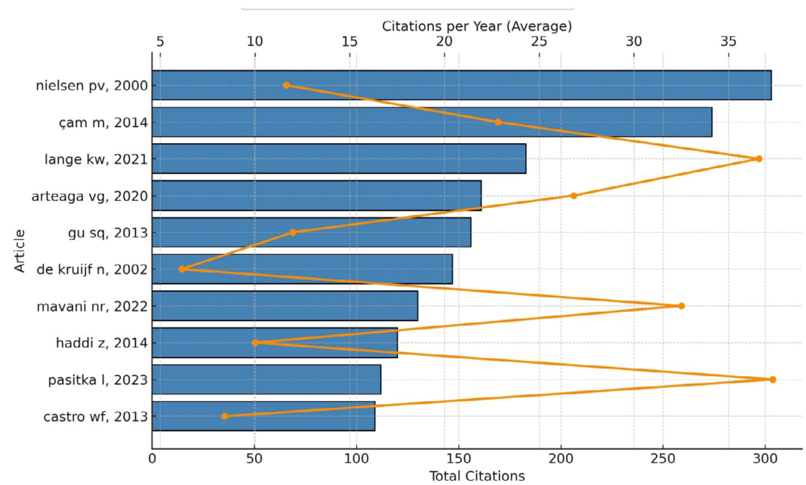

Figure 2. Most cited articles and their average annual impact.

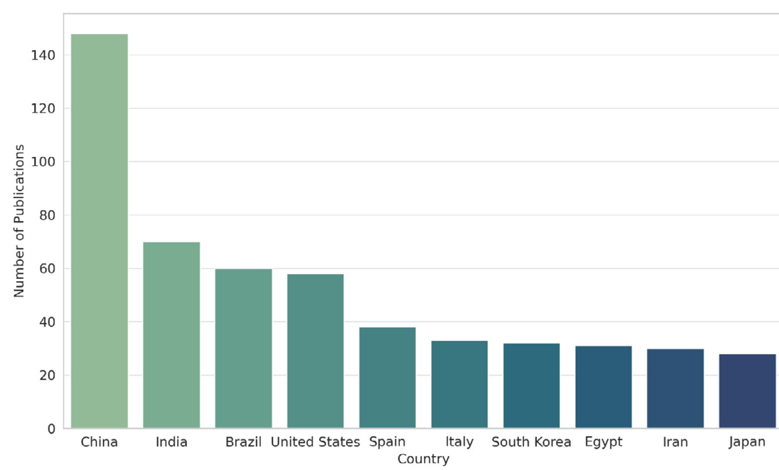

Figure 3. Top ten countries by scientific output.

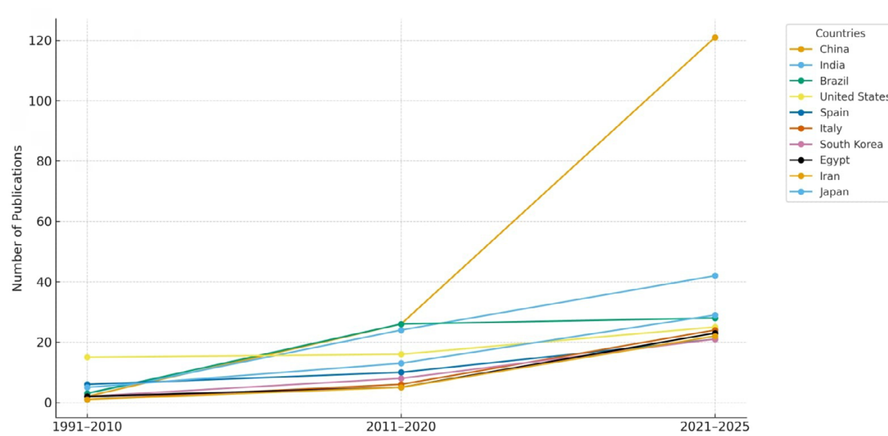

Figure 4. Evolution of the number of publications by country in the periods 1991–2010, 2011–2020, and 2021–2025.

productive countries. The presence of countries from various continents in this group demonstrates the global and interdisciplinary nature of the field, which spans from the technological development of intelligent systems to their practical application across the food production chain.

Figure 4 shows the evolution in the number of publications from the 10 most productive countries, distributed across three periods: 1991–2010, 2011–2020, and 2021–2025. A general increase is observed from 2011 onward, with an even more pronounced rise between 2021 and 2025, indicating a recent intensification of scientific activity on the topic. Most countries followed an upward trajectory, although with varying rates of growth.

China stands out, showing a remarkable acceleration in the last 5-year period, distancing itself from the other countries in terms of total publications. India, Brazil, and Japan also experienced consistent growth during the period, while countries such as the United States, Spain, Italy, and South Korea maintained stable performances, though with less intensity. The temporal distribution highlights the recent consolidation of the field and the expansion of international interest, with the emergence of new scientific hubs.

3.2.2 Most productive authors

With regard to authorship, there is a significant dispersion of scientific output among researchers. Of the 200 identified authors, 161 published up to two articles and 29 contributed with up to three publications—indicating a field in expansion, still marked by sporadic and occasional contributions. Only 10 authors stood out for more consistent output, with four to six articles each, totaling 29 publications, which represents just 3.9% of the 735 articles analyzed. This finding reinforces the absence of strong authorial concentration and points to a diverse scientific community in which few researchers maintain continuous work on the topic.

Among the most productive authors (Figure 5) are Sigfredo Fuentes and Claudia Gonzalez Viejo, both from the University of Melbourne (Australia), with six articles each. Next, with five publications each, are Hong Men, Yan Shi, and Xiuxin Xia, all affiliated with the Northeast Electric Power University (China). Authors with four publications include Maria Dolores del Castillo (Consejo Superior de Investigaciones Científicas, Spain), Sueli Rodrigues (Federal University of Ceará, Brazil), Luca Settanni (University of Palermo, Italy), Kandi Sridhar (Fu Jen Catholic University, Taiwan), and Damir D. Torrico (University of Illinois Urbana-Champaign, United States).

The institutional and geographic background of the most productive authors reflects the internationalization of research in this area. Notably, there is a relative concentration in Australia and China, which are home to five of the 10 most productive researchers—suggesting the existence of active and recurrent research hubs in these regions. Although the number of publications remains limited, this configuration points to the presence of structured research lines and thematic continuity. Identifying these authors is important not only for recognizing emerging leaders but also for mapping collaborative networks, fostering institutional partnerships, and guiding the strengthening of integrated scientific research strategies.

3.3 Co-occurrence analysis and thematic clustering

Based on the mapping of 69 terms using the VOSviewer software, it was possible to identify a complex and interconnected cognitive structure composed of seven thematic clusters. The most central terms in the network include *"sensory analysis," "machine learning," "quality," "prediction/predictive," "artificial neural network,"* and *"deep learning,"* highlighting the centrality of computational approaches in the evaluation and prediction of sensory attributes. Studies such as Gonzalez Viejo et al. (2019) reinforce this trend by demonstrating the application of AI models—such as machine learning, deep learning, and e-noses—to predict consumer preferences based on physiological signals and physicochemical data, enhancing the objectivity, efficiency, and accuracy of computer-assisted sensory analyses.

The co-occurrence analysis (Figure 6) reveals a strong interdisciplinary nature, with the presence of terms associated with food science, analytical chemistry, data science, nutrition, multivariate statistics, and computational engineering.

Cluster 1 (red) includes terms such as *aroma, flavor, taste, deep learning,* and *natural language processing*, reflecting research focused on the identification and modeling of complex sensory attributes, including volatile compounds and descriptive language.

Cluster 2 (green) emphasizes the physicochemical characterization of meat products, with terms such as *beef, meat, pork, muscle,* and *lipid oxidation*, highlighting studies applied to meat quality and authenticity assessment.

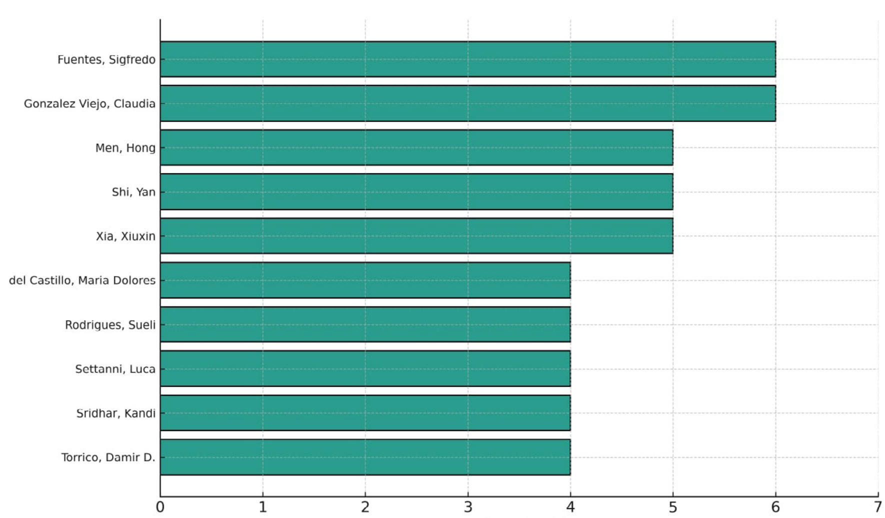

Figure 5. Most productive authors.

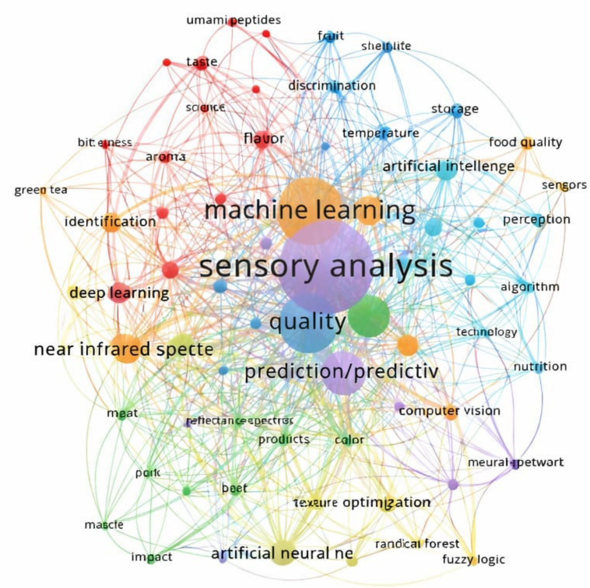

Figure 6. Co-occurrence network of terms extracted from the titles, abstracts, and keywords of publications.

Cluster 3 (orange) focuses on instrumental approaches based on *reflectance spectroscopy, products, discrimination,* and *temperature*, aimed at the objective evaluation of sensory attributes and physical parameters.

Cluster 4 (yellow) brings together advanced AI techniques such as *artificial neural network, feature extraction, fuzzy logic, genetic algorithm,* and *optimization*, focusing on predictive modeling, automated classification, and simulation of food properties.

Cluster 5 (purple), composed of terms such as *sensory analysis, prediction/predictive, parameters,* and *support vector machine*, represents the methodological core of the field, highlighting the frequent use of supervised learning and robust statistical methods for sensory prediction.

Cluster 6 (blue) links sensory perception to nutrition, with terms like perception, algorithm, response, and technology, emphasizing the relationship between sensory attributes, physiological responses, and nutritional value. Finally, Cluster 7 (cyan) concentrates terms related to the application of sensors and computer vision, such as computer vision, near-infrared spectroscopy, food quality, electronic nose, and green tea, revealing the growing adoption of digital technologies in food evaluation.

The structure of the network reveals not only the consolidation of AI use in sensory science but also points to emerging trends, such as the application of hybrid models, personalized nutrition, and the convergence between sensory prediction and nutritional value. According to Van Eck and Waltman (2010), visual representations such as this provide valuable insights for identifying well-established lines of research and underexplored gaps, offering a solid foundation for new scientific and technological developments in the field of smart food systems.

4 CONCLUSIONS

The results of this study reveal a significant increase in scientific output focused on the application of AI in sensory science, especially from 2016 onward. The bibliometric analysis enabled the mapping of publication dynamics, the identification of the most productive authors and countries, the most impactful articles, and the leading journals in the field. A substantial concentration of publications was observed in China, India, and Brazil, reflecting the involvement of emerging countries in advancing technological innovation in the area. The keyword co-occurrence analysis revealed seven interconnected thematic clusters, highlighting techniques such as machine learning, artificial neural networks, fuzzy logic, computer vision, and electronic sensors applied to the prediction of sensory attributes.

These findings demonstrate not only the maturation of the field but also its increasing complexity and interdisciplinarity, with contributions that integrate food science, computer science, engineering, and statistics. This study provides a solid empirical foundation for researchers, institutions, and companies seeking to understand the structure, key contributors, and emerging trends at the interface between AI and sensory science. By systematizing the existing body of research and identifying knowledge gaps, this study contributes to guiding new research agendas and strengthening innovation in the food sector.

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