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NUTRIGENOMICS, FUNCTIONAL FOODS, AND FOOD ENGINEERING: BIBLIOMETRIC TRENDS TOWARD HEALTHY AND SUSTAINABLE EATING

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ABSTRACT:

The interrelationship between nutrition, health, and sustainability has become a central focus of contemporary scientific research. The transition toward healthier and more sustainable food systems demands integrative approaches that combine nutritional knowledge, technological innovation, and molecular understanding. In this context, nutrigenomics, functional foods, and food engineering emerge as strategic pillars to address pressing challenges such as obesity, non-communicable chronic diseases, and metabolic decline, while simultaneously promoting the conservation of natural resources and equitable access to adequate nutrition. This study seeks to answer the question: Can a term co-occurrence network analysis identify emerging trends in nutrigenomics, functional foods, food engineering, and healthy and sustainable nutrition? To this end, a bibliometric analysis was conducted using a network of 1,342 conceptual terms defined by 550 authors. The results revealed four thematic clusters: Cluster 1 Nutritional bioactives, molecular regulation, and emerging technologies for health and food performance; Cluster 2 Clinical intervention and functional compounds for the prevention of metabolic and cardiovascular diseases; Cluster 3 Personalized nutrition, gut microbiota, and dietary patterns in the prevention of chronic diseases; and Cluster 4 Personalized nutrition, pharmacotherapy, and precision medicine in the management of obesity and metabolic disorders. The findings provide a foundation for the development of new lines of research, which should be further explored and formalized through the application of robust methodologies such as structural equation modeling and factorial analysis.

Keywords: Nutrigenomics, functional foods, healthy nutrition, bibliometrics, Python

INTRODUCTION

The relationship between nutrition, health, and sustainability has emerged as a priority on the international scientific agenda. In the face of rising non-communicable chronic diseases, global food systems are challenged to provide products that are not only safe and accessible, but also personalized, preventive, and environmentally responsible [1]. Within this framework, the integration of nutrigenomics, functional foods, and food engineering represents a strategic convergence toward a new generation of dietary practices grounded in scientific evidence, cutting-edge technology, and sustainability principles [2], [3].

Nutrigenomics, as a central discipline within precision medicine, enables the understanding of how nutrients influence gene expression and how individual genomes modulate the response to different dietary patterns. This ability to tailor nutrition to genetic profiles has proven crucial in the prevention and management of complex diseases such as diabetes, obesity, cancer, and cardiovascular disorders, through the integration of data from genomics, transcriptomics, and gut microbiota [4], [5]. For example, recent studies have shown that certain genetic profiles may respond differently to the intake of polyunsaturated fatty acids, affecting systemic inflammation and lipid metabolism [3], [5].

In parallel, the development of functional foods has evolved from generalist approaches to highly specific solutions, with a growing incorporation of plant-derived bioactive compounds, prebiotics, probiotics, and

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bioactive peptides that modulate immunological, antioxidant, and neuroendocrine processes [6]. The scientific literature also highlights the reformulation of traditional products to enhance their nutritional profile without compromising palatability or cultural acceptability, through the incorporation of functional ingredients derived from agro-industrial by-products, thereby strengthening sustainability across the entire value chain [6], [7].

Food engineering, in turn, serves as a vehicle for translating these scientific advances into viable and scalable products. Technologies such as micronutrient encapsulation, non-thermal processing (ultrasound, high pressure, pulsed electric fields), 3D printing of personalized foods, and the design of smart packaging enable the preservation of functional properties and the extension of shelf life [6]. These advances not only meet the demands of an increasingly informed consumer but also contribute to reducing the environmental footprint of industrial processes, particularly when alternative sources such as algae, fungi, insects, or cultured proteins are integrated [8].

From a bibliometric perspective, the analysis of scientific output in these areas reveals an exponential growth in publications, particularly since 2018, with thematic epicenters focused on artificial intelligence applied to food formulation, the utilization of secondary metabolites, nanotechnology for targeted nutrient delivery, and the use of genetic biomarkers to validate functional effects [3]. This dynamism is reflected in broad interinstitutional and transdisciplinary collaboration, bringing together biotechnologists, nutritionists, food engineers, geneticists, and public health specialists [6].

However, this process of convergence also raises important bioethical, social, and regulatory questions. Unequal access to genetic sequencing technologies, the protection of genomic data, the scientific validation of functional benefits, and the cultural appropriation of designed foods are dimensions that still require robust regulatory frameworks and participatory approaches [7]. Likewise, the implementation of public policies that integrate personalized nutrition with environmental sustainability represents one of the greatest challenges facing contemporary food systems.

Taken together, the bibliometric analysis of the fields of nutrigenomics, functional foods, and food engineering reveals not only a quantitative expansion of research but also a qualitative transformation of the global food paradigm. This transformation is oriented toward more resilient production systems, scientifically grounded food product design, and public health strategies based on both individual and collective biology.

Advances in Nutrigenomics and Personalized Medicine

The development of nutrigenomics has profoundly transformed the conception of the human diet, positioning nutrition as a tool for personalized intervention based on genetic profiling. This discipline is grounded in the understanding of how nutrients influence gene expression and how individual variations in DNA modify the metabolic and physiological responses to specific foods. This bidirectional interaction enables the design of tailored dietary plans, particularly relevant for the prevention of complex diseases such as obesity, hypertension, type 2 diabetes, and cancer [3], [4].

One of the most significant advances in this area has been the integration of omics technologies (genomics, transcriptomics, metabolomics, and epigenomics) with artificial intelligence and machine learning algorithms, which has enabled the development of accurate and scalable predictive models. These models help identify the most beneficial type of diet for an individual based on their genetic variants, reducing the "one-size-fits-all" approach and promoting precision health strategies [9]. The literature indicates that certain polymorphisms in genes such as *FTO*, *APOE*, or *MTHFR* are directly associated with individual responses to nutrients such as fatty acids, folate, or simple sugars [10].

In parallel, nutrigenomic studies have revealed the modulatory role of the gut microbiota on gene expression. Intestinal bacteria not only metabolize dietary components but also release metabolites that interact with the human epigenome, directly influencing inflammation, oxidative stress, and metabolic homeostasis [11], [12]. This microbial dimension is being incorporated into precision nutrition platforms, which now include microbiome analysis as a key indicator for the design of personalized functional diets [9].

However, the clinical implementation of nutrigenomics faces ethical and regulatory challenges. The management of sensitive genetic data, equitable access to sequencing tests, and the scientific validation of specific dietary

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interventions are aspects that demand robust regulatory frameworks. In addition, specialized training is needed for healthcare professionals who will apply this knowledge in clinical settings [7], [13].

The consolidation of nutrigenomics as a cornerstone of preventive medicine marks a transition toward more personalized, proactive, and evidence-based healthcare models. This shift redefines the role of nutrition not merely as a cultural or isolated nutritional act, but as a strategically targeted medical intervention.

Functional Foods and Bioactive Compounds as a Public Health Strategy

Functional foods represent an evolution from traditional nutrition toward purpose-driven, therapeutic eating. Defined as products that, beyond their basic nutritional value, provide additional health benefits, these foods incorporate bioactive compounds that modulate specific physiological functions. Recent scientific literature has documented a sustained increase in research focused on ingredients such as polyphenols, carotenoids, essential fatty acids, probiotics, bioactive peptides, and fermentable dietary fiber [6], [14].

One of the most relevant aspects is the ability of these compounds to influence key processes such as oxidative stress, low-grade chronic inflammation, and immune function. For instance, polyphenols found in fruits and vegetables have demonstrated cardioprotective, antitumor, and neuroprotective effects by modulating cellular signaling pathways such as NF-κB and Nrf2 [57], [45]. Likewise, omega-3 fatty acids and probiotics have been associated with improvements in gut health, modulation of the gut–brain axis, and the prevention of metabolic diseases [9].

An important advancement in this field is the reformulation of traditional foods through the addition of functional ingredients without altering their sensory characteristics. This strategy expands access to these products without disrupting deeply rooted dietary habits. In parallel, research is exploring the use of agro-industrial by-products (such as peels, seeds, and pulp) as rich sources of bioactive compounds, thereby promoting a circular economy model and sustainable production practices.

In addition to their individual benefits, functional foods are increasingly being positioned as strategic tools in public health, particularly in the context of population aging, nutritional transition, and the rising prevalence of non-communicable diseases. Some studies are focused on designing targeted products for pregnant women, older adults, patients with inflammatory diseases, or individuals with specific immunological needs [15].

The scientific validation of functional effects, however, remains a challenge. The efficacy of these compounds depends on factors such as bioavailability, effective dosage, ingredient synergy, and the genetic variability of the consumer. Therefore, rigorous clinical studies are needed to substantiate the health claims associated with these products [5].

Technological Innovations in Food Engineering

Food engineering has undergone a profound transformation over the past two decades, embracing disruptive technologies that address both public health demands and sustainability imperatives. This field is dedicated to designing, optimizing, and scaling industrial processes for the production of safe, nutritious, functional, and environmentally friendly foods. In this context, technological innovations aim not only to preserve nutrients and extend product shelf life but also to facilitate the formulation of personalized foods with high functional value.

Among the most relevant emerging technologies are non-thermal processes such as high hydrostatic pressure, high-intensity pulsed electric fields, and ultraviolet light treatment. These techniques allow for better preservation of thermosensitive bioactive compounds such as vitamins, antioxidants, and enzymes which is crucial in the production of functional foods [16]. Similarly, nutrient nanoencapsulation has gained prominence as a strategy to improve the stability, bioavailability, and controlled release of functional compounds. For example, systems based on nanoemulsions, liposomes, and natural biopolymers have been developed to encapsulate polyphenols, fatty acids, or antimicrobial compounds [14].

Another innovative line is 3D food printing, which enables the creation of personalized food matrices in terms of shape, composition, and texture, tailored to the specific nutritional needs of different population groups (such as children, the elderly, or patients with dysphagia). This technology opens up a promising horizon for the design of medically targeted and culturally acceptable diets [6], [15].

La sostenibilidad también ha tenido una fuerte influencia en la ingeniería alimentaria. El uso de residuos agroindustriales como materia prima para la producción de ingredientes funcionales, colorantes naturales, biopolímeros y envases biodegradables es una tendencia en expansión. Por ejemplo, se han desarrollado envases activos e inteligentes que no solo prolongan la vida útil de los alimentos, sino que también detectan cambios de temperatura, pH o contaminantes, mejorando así la trazabilidad y la seguridad alimentaria [17], [18].

In addition, automated monitoring systems based on sensors, artificial intelligence, and predictive analytics are being integrated to optimize real-time quality control. This transition toward Industry 4.0 enables the reduction of food waste, maximization of energy efficiency, and assurance of complete traceability from origin to consumer [9], [13].

In summary, contemporary food engineering goes beyond preservation or formulation processes; it functions as a technological pillar that integrates nutritional functionality, sensory experience, and environmental sustainability. This integrative approach is essential to addressing the health, ethical, and ecological challenges posed by 21st-century food systems.

Convergence Toward Resilient and Sustainable Food Systems

The contemporary approach to healthy eating has transcended the boundaries of individual nutrition to incorporate social, ecological, and technological dimensions within a holistic food system model. This transition involves not only improving the nutritional quality of food products but also ensuring that their production, distribution, and consumption align with principles of equity, environmental sustainability, and structural resilience. In this context, the convergence of nutrigenomics, functional foods, and food engineering represents a strategic response to global challenges in public health, climate change, and food security [19], [20].

Various studies highlight how these fields are increasingly interconnected to generate comprehensive food solutions that take into account the genetic characteristics, cultural profile, and environmental context of populations. For example, functional foods designed based on principles of personalized nutrition aim not only to improve individual health but also to reduce the burden of chronic diseases on public health systems [21], [22]. In turn, these products are being formulated with ingredients derived from sustainable sources, such as agro-industrial residues, plant-based by-products, and alternative proteins (e.g., algae, insects, mycoproteins), significantly reducing the environmental impact of the food system [6].

Desde una perspectiva de política alimentaria, se observa un creciente interés por incorporar los avances científicos en nutrigenómica y funcionalidad alimentaria en programas de salud pública, guías alimentarias nacionales y estrategias de prevención nutricional [3]. Esto requiere una estrecha colaboración entre sectores gubernamentales, académicos e industriales, así como la participación activa de comunidades locales para asegurar la pertinencia cultural y la aceptación social de los productos desarrollados [23], [24].

Moreover, bibliometric analysis reveals a strong correlation between the evolution of scientific knowledge in these fields and the Sustainable Development Goals (SDGs), particularly in the areas of good health and well-being (SDG 3), responsible consumption and production (SDG 12), and climate action (SDG 13) [25], [26]. Within this framework, researchers are proposing evaluative models that integrate indicators of nutritional sustainability, resource-use efficiency, environmental impact, and food justice.

However, structural and ethical barriers still need to be addressed to consolidate this emerging paradigm. Key challenges include inequality in access to genomic technologies, the need for regulation of functional food labeling, the protection of personal data, and the cultural appropriation of designed foods [11]. These concerns must be taken into account when formulating responsible innovation policies in the field of nutrition.

Finally, it is recognized that the path toward truly resilient and sustainable food systems requires a transdisciplinary approach that integrates knowledge from the biological, social, economic, and technological sciences. This approach will not only enable the prevention of disease and the promotion of well-being but also support the preservation of ecosystems, the protection of food biodiversity, and the assurance of nutritional security for future generations.

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Applications of the PRISMA Methodology in Nutrigenomics and Functional Foods

The PRISMA methodology (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) has become a key tool for synthesizing scientific evidence in a rigorous and transparent manner. Its application in the fields of nutrigenomics and functional foods has enabled the structuring of systematic reviews that integrate genetic, dietary, and clinical data with high precision. In the study by Pérez-Beltrán et al. (2022), the PRISMA methodology was employed to analyze the interaction between genetic variants related to lipid metabolism and plasma responses to various nutrients or dietary supplements, thereby establishing personalized dietary recommendations.

The methodological process, registered in PROSPERO (CRD42021248816), included a systematic search in PubMed and ScienceDirect covering the period from 2010 to 2020, selecting studies conducted on humans, published in English, and reporting statistically significant results. Using the PRISMA flow diagram, the exclusion of 1,080 articles was documented, ultimately narrowing the selection to 38 high-quality studies, evaluated using the Jadad and Newcastle-Ottawa scales. This application enabled not only the identification of associations between polymorphisms and macronutrients (fats, carbohydrates, proteins) but also the validation of interventions with nutraceuticals such as omega-3, phytosterols, and plant extracts, with dietary recommendations categorized according to levels of scientific evidence [27].

The PRISMA approach thus contributes to the consolidation of precision nutrition by offering a robust and reproducible synthesis of emerging knowledge, thereby strengthening the scientific basis for public policies, clinical guidelines, and personalized dietary strategies.

Bibliometric Studies in Nutrigenomics and Functional Foods

The application of bibliometrics in the field of nutrigenomics and functional foods has enabled a structured overview of the evolution of scientific knowledge, key thematic areas, and international collaborations shaping this interdisciplinary domain. Bibliometric analysis reveals sustained growth in academic output related to bioactive compounds, prevention of metabolic diseases, and personalized nutrition, reflecting the increasing interest in evidence-based dietary strategies.

A strong concentration of studies has been identified that explore the beneficial effects of functional foods on diseases such as obesity, type 2 diabetes, and cardiovascular disorders. Natural compounds such as polyphenols, antioxidants, phytochemicals, and probiotics are frequently cited in the literature as key elements in the modulation of relevant physiological processes, including lipid metabolism regulation, inflammatory response, and insulin sensitivity [28].

In parallel, nutrigenomics has gained prominence as a central pillar of personalized medicine, with an approach aimed at tailoring dietary recommendations to the genetic characteristics of each individual. The scientific literature has documented a growing body of research addressing gene–nutrient interactions, particularly concerning polymorphisms such as *FTO*, *APOE*, and *MTHFR*, which have been linked to the body's response to macronutrients and functional supplements [29].

Bibliometrics has also enabled the identification of major thematic clusters within the field, highlighting areas such as nutritional functionality, nutritional epigenetics, nutraceuticals, and the integration of technologies like artificial intelligence and bioinformatics. These tools have facilitated the processing of large volumes of genetic, clinical, and nutritional data, enhancing the development of predictive platforms for personalized dietary interventions [30].

Taken together, bibliometric studies on nutrigenomics and functional foods not only systematize the accumulated knowledge but also provide strategic insights to guide public health policies, promote technological innovation in the food industry, and foster high-impact collaborative research at the global level.

Quality of High-Quartile Publications in the Fields of Nutrigenomics and Functional Foods

Scientific development in the fields of nutrigenomics and functional foods has achieved high standards of quality, as evidenced by the growing number of publications in top-tier journals (Q1 and Q2) indexed in databases such as Scopus and Web of Science. This positioning is closely linked to methodological rigor, technological innovation, and the relevance of reported findings factors that contribute to greater academic and societal impact. Research published in high-quartile journals tends to share common characteristics, including clearly defined

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scientific objectives, the use of advanced experimental methodologies, practical applicability of results, and participation in international collaboration networks [31], [32], [33].

One of the key strengths that defines the quality of these publications is their interdisciplinary approach. High-impact research integrates knowledge from molecular biology, nutritional genetics, gut microbiota, epigenetics, and food engineering. This convergence enables a more holistic understanding of the interactions between nutrients, genes, and non-communicable chronic diseases such as cancer, diabetes, and obesity [34]. In addition, the use of omics tolos such as transcriptomics, metabolomics, and proteomics is widely documented in studies published in leading journals in the field, reflecting a strong commitment to the analysis of complex biological systems through high-resolution approaches [35], [36].

Another distinguishing feature of high-quartile publications is the level of innovation in analytical models. There has been an increasing use of machine learning algorithms and bioinformatics tools to predict personalized dietary responses, representing a qualitative leap in the precision of nutritional recommendations based on genomic data [37], [38]. These strategies are aligned with the goals of personalized medicine and precision nutrition, highlighting the strategic value of such studies for public health systems and the food industry [39], [40].

Quality is also reflected in the statistical robustness of experimental designs, with a predominance of controlled clinical trials, double-blind studies, and systematic meta-analyses. These rigorous methodologies, combined with PRISMA-based reviews and bibliometric trend analyses, enable reliable knowledge synthesis and ensure the reproducibility of results [41], [42]. Likewise, there is a strong presence of publications in English with high citation rates, led by academic institutions from Western Europe, North America, and East Asia, which reinforces their global visibility [43], [44].

It is worth highlighting that the most influential articles in high-quartile journals also exhibit precise content structuring, with clearly defined sections that include up-to-date background information, robust theoretical frameworks, results featuring graphical representations of omics data, and discussions that integrate both clinical implications and future projections. This structuring not only facilitates scientific readability but also demonstrates a commitment to transparency, publication ethics, and knowledge transfer [45], [46].

Finally, research funding from European programs, the NIH, technological innovation agencies, and private foundations is also closely linked to the quality and visibility of published articles. Such funding enables access to cutting-edge technology, the recruitment of representative cohorts, and the long-term sustainability of research lines factors that significantly enhance the overall quality of scientific outputs.

In summary, the quality of high-quartile publications in nutrigenomics and functional foods is not an isolated phenomenon, but rather the result of a strategic alignment of experimental design, scientific rigor, technological innovation, and global collaboration. These elements position these fields as fundamental pillars in the transition toward more personalized, sustainable, and evidence-based healthcare systems [47], [48].

The present study poses the following research question: *Can a term co-occurrence network analysis identify emerging trends in nutrigenomics, functional foods, food engineering, and healthy and sustainable nutrition?* In addition, the following hypothesis is proposed:

H1: The analysis of term co-occurrence networks effectively enables the identification of key thematic trends and emerging research lines in the fields of nutrigenomics, functional foods, food engineering, and healthy and sustainable nutrition.

The growing scientific output on nutrigenomics, functional foods, and food engineering reflects a heightened interest in understanding and transforming the relationship between nutrition, human health, and global sustainability. This interdisciplinary field has expanded toward more integrative approaches, where the interaction between nutrients and gene expression (nutrigenomics), the design of bioactive compounds (nutraceuticals), and emerging technologies in food processing converge to address contemporary challenges such as the nutritional syndemic, which combines obesity, undernutrition, and climate change.

In this context, bibliometric tools enable the systematization of scientific evidence and the mapping of knowledge dynamics. In particular, term co-occurrence network analysis has become a rigorous method for revealing

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thematic structures, patterns of conceptual association, and emerging areas within large volumes of scientific literature. This approach allows for the identification of the most frequent concepts and their interrelationships, which is essential for outlining current and future trends in a complex and evolving field.

Several reviewed studies show that the field has shifted from a perspective focused solely on nutritional benefits toward a more comprehensive orientation that includes the prevention of chronic diseases, the personalized design of diets, and the development of sustainable technologies for food production. These transformations are semantically captured in the literature through key terms whose co-occurrence can be represented and analyzed in the form of a network.

Therefore, the hypothesis that term co-occurrence network analysis effectively enables the identification of key thematic trends and emerging research lines in the fields of nutrigenomics, functional foods, food engineering, and healthy and sustainable nutrition is supported by the ability of these tools to reflect the semantic and epistemological transformations of the field. This bibliometric approach not only validates the consolidation of certain research lines but also helps identify gaps, unexplored conceptual relationships, and opportunities for scientific and technological convergence.

METHODOLOGY

Document Selection

To define the corpus of documents, the recommendations of the PRISMA methodology were applied (see Figure 1). Based on the selection of the Scopus and Web of Science databases, the corresponding search equations were designed (see Table 1).

Figure 1. Flow diagram PRISMA

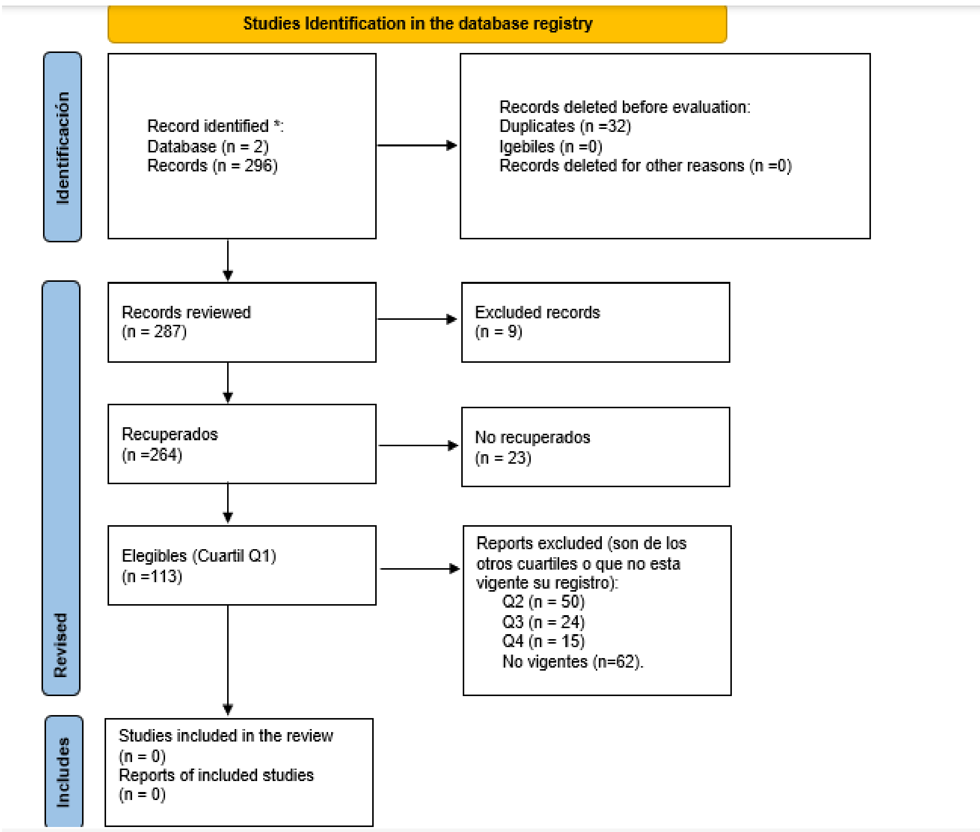

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Table 1. Search equation

Data base	Search equation	t. Doc
Scopus	TITLE-ABS-KEY (("nutrigenomics" OR "nutrigenomic" OR "nutritional genomics")) AND TITLE-ABS-KEY (("functional foods" OR "nutraceuticals" OR "bioactive compounds")) AND TITLE-ABS-KEY (("nutrition" OR "human health" OR "metabolic health" OR "dietary intervention")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re"))	143
Web of Science	("nutrigenomics" OR "nutrigenomic" OR "nutritional genomics") (All Field) And (("functional foods" OR "nutraceuticals" OR "bioactive compounds")) (All Field) And (("nutrition" OR "human health" OR "metabolic health" OR "dietary intervention"))	153
	Total	296

Workflow

To carry out the proposed bibliometric analysis, the following workflow was implemented:

1. Records were downloaded from each database and saved in .bib format files.
2. A Python script was developed to integrate and remove duplicate entries, generating a single final .bib file.
3. A second Python script was used to classify the articles according to journal quartiles and select those in Q1.
4. Using the Bibliometrix package (version 5) in R, the main bibliometric indicators were extracted.
5. With the VOSviewer software (version 1.6.20), a conceptual term co-occurrence network defined by the authors was constructed.
6. A Python script was developed to extract quartile classifications and defined clusters from the JSON output of the term network.

RESULTS

Analysis of Key Bibliometric Indicators

The bibliometric analysis of scientific production in the fields of nutrigenomics, functional foods, and food engineering, with a focus on health and sustainability, covers the period from 2004 to 2025 (see Figure 2A). It reveals a body of 88 documents published across 57 distinct sources, including scientific journals, books, and conference proceedings. This output exhibits an annual growth rate of 11.03%, indicating a sustained upward trend in academic attention to these interdisciplinary topics.

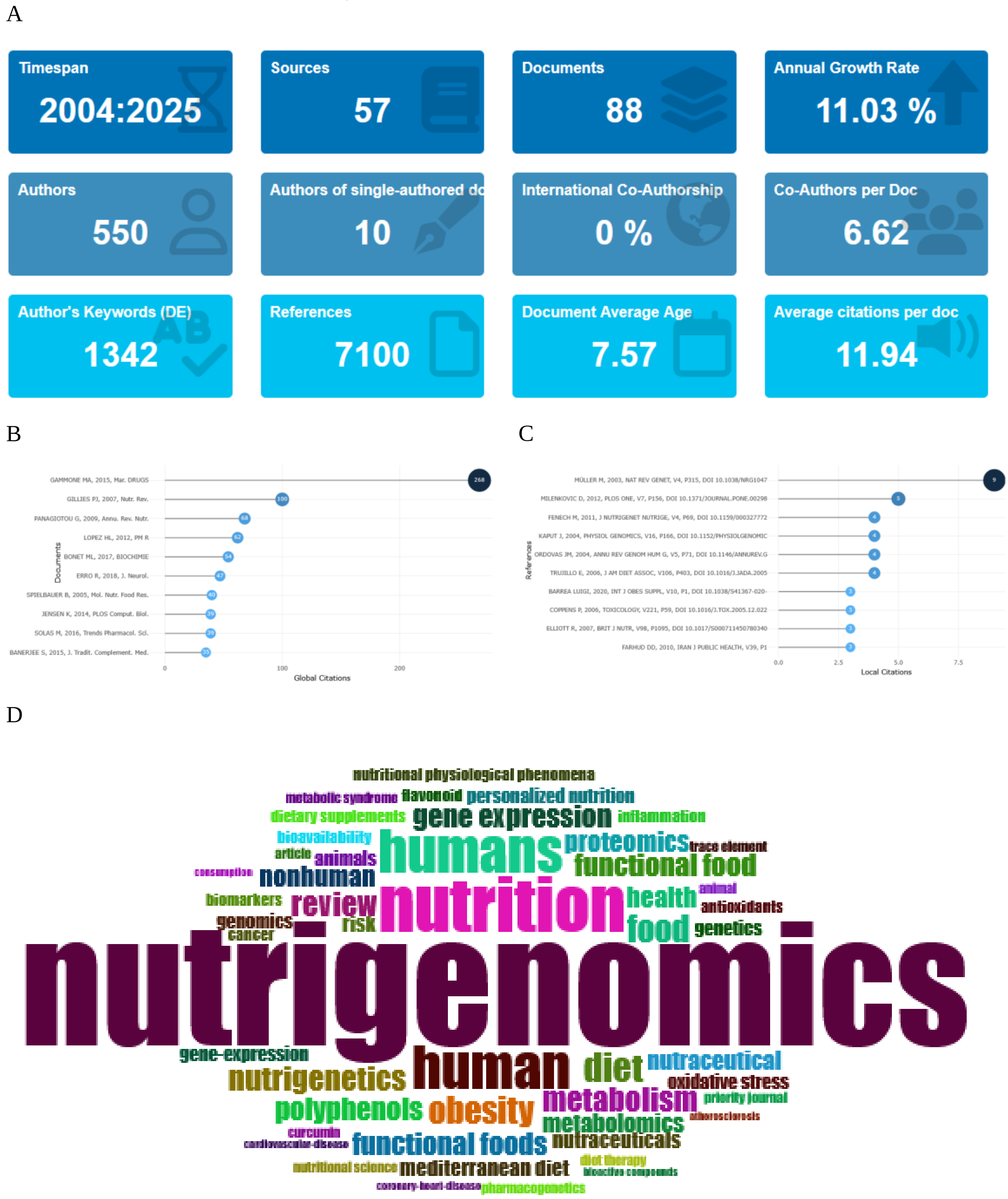
In terms of impact, the documents show an average of 11.94 citations per publication, reflecting a moderate level of academic influence (see Figure 2B). The average age of the documents is 7.57 years, suggesting that the field is in a recent stage of consolidation, with both historical and contemporary contributions playing a significant role. Altogether, the analyzed publications contain over 7,100 references, indicating a broad and well-established theoretical and empirical foundation.

Regarding thematic content, 943 terms were identified in Keywords Plus (ID) and 1,342 author-provided keywords (DE), indicating notable semantic richness and diversity of approaches. This thematic breadth is essential for the co-occurrence network analysis, as it enables precise mapping of emerging conceptual trends related to the interaction between food, health, and sustainability (see Figure 2D).

In terms of authorship, the 550 identified authors reflect a broad and diverse scientific community. However, only 10 documents were written by a single author, highlighting the predominantly collaborative nature of the field. This pattern is further supported by an average of 6.62 co-authors per document. Notably, no international collaborations were recorded (0%), indicating a potential area for growth through the promotion of global networks that integrate knowledge and experiences from multiple regions.

Taken together, these quantitative results confirm that scientific production on nutrigenomics, functional foods, and food engineering linked to health and sustainability has experienced steady growth. It is characterized by high levels of author collaboration and an emerging thematic concentration, which will be further explored through semantic network analysis in the following section.

Figure 2. Bibliometric Measures



Note: A) Bibliometric measures. B) Most Global Cited Documents. C) Most Local Cited References. C) WordCloud

Term Co-Occurrence Network Analysis

To construct the co-occurrence network, 1,342 conceptual terms defined by 550 authors were used. Four clusters were identified, concentrating the strongest relationships among the terms. The first cluster was named:

Nutritional bioactives, molecular regulation, and emerging technologies for health and food performance. The second cluster was defined as: *Clinical intervention and functional compounds for the prevention of metabolic and cardiovascular diseases*. The third cluster was titled: *Personalized nutrition, microbiota, and dietary patterns in the prevention of chronic diseases*. Finally, the fourth cluster was defined as: *Personalized nutrition, pharmacotherapy, and precision medicine in the management of obesity and metabolic disorders*. In the following section, we present the literature review for each of these clusters.

Cluster 1: Nutritional Bioactives, Molecular Regulation, and Emerging Technologies for Health and Food Performance

This cluster encompasses research situated at the intersection of nutritional biochemistry, advanced nutraceuticals, and molecular and nanotechnological engineering strategies applied to food and health. The co-occurrence of terms such as *nutraceutical*, *gene expression*, *oxidative damage*, *chitosan nanoparticles*, and *growth performance* reveals a research focus on: optimizing the biological and functional performance of foods; regulating cellular and genetic processes through nutrient intervention; designing delivery systems and transport technologies for bioactive compounds; and combating pathologies associated with oxidative stress and mitochondrial dysfunction. This cluster represents one of the most prominent emerging axes toward personalized, functional nutrition grounded in advanced molecular science. It contributes to sustainability by optimizing the use of bioactive resources and improving population health outcomes (see Figure 3A).

The growing interest in the relationship between diet, health, and biotechnology has driven the consolidation of an interdisciplinary field focused on nutritional bioactives and their impact on the molecular regulation of key physiological functions. This thematic cluster brings together an expanding body of research linking naturally derived functional compounds with improved metabolic performance, chronic disease prevention, and overall well-being optimization. Scientific evidence highlights the role of secondary metabolites such as polyphenols, flavonoids, and alkaloids in modulating cellular pathways associated with inflammation, oxidative stress, and cellular aging [16].

A central axis of this cluster is the understanding of the molecular mechanisms through which bioactive compounds exert therapeutic or preventive effects. Recent studies have shown that plant-derived extracts such as those from green tea, turmeric, black garlic, and wild berries activate key cellular signaling pathways, including Nrf2/ARE, NF-κB, and AMPK, which are involved in antioxidant and anti-inflammatory responses [49]. This molecular regulation has implications not only for preventive nutrition but also for the development of functional foods with clinical applications in patients with metabolic disorders or neurodegenerative diseases [24].

In addition, the cluster incorporates an emerging technological approach by integrating food engineering tools, nanotechnology, and smart compound encapsulation techniques to enhance the bioavailability of these bioactives within complex food matrices [50]. For example, the encapsulation of curcumin and resveratrol in nanoliposomes has been shown to enhance their intestinal absorption and prolong their systemic antioxidant effects, representing a promising strategy in the formulation of personalized nutraceuticals [50]. These technologies not only stabilize sensitive compounds but also enable their targeted release to specific tissues through smart delivery systems, thereby expanding the horizon of therapeutic nutrition [9].

Another relevant aspect of the cluster is the link between precision nutrition and personalized health. Nutrigenomics has enabled the identification of specific gene nutrient interactions, allowing for dietary interventions tailored to an individual's genetic profile [6]. These strategies aim to optimize the body's response to functional diets by minimizing risks and maximizing benefits according to the individual's metabolic context. In parallel, there is a growing emphasis on integrating the gut microbiome as a key mediator in the absorption and biotransformation of bioactive compounds, opening new research avenues in microbiotic and metabolomic synergies [51].

In sum, this cluster highlights a multidimensional approach that integrates basic science, technological innovation, and clinical applications centered on nutritional bioactives. Its advancement represents a strategic contribution toward healthier, more sustainable, and personalized nutrition aligned with the health challenges of the 21st century.

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Cluster 2: Clinical Intervention and Functional Compounds for the Prevention of Metabolic and Cardiovascular Diseases
This cluster encompasses clinical and experimental studies that assess the impact of functional foods and bioactive compounds in the prevention of cardiovascular disease, metabolic dysfunction, and obesity within the framework of evidence-based nutrition. The associated terminology reveals several key aspects: the use of controlled clinical trials as the gold standard for validating the efficacy of food-based interventions; the measurement of metabolic and cardiovascular risk biomarkers; the investigation of bioactive components such as flavonoids, carotenoids, and vitamins within food matrices including fortified juices, citrus fruits, and vegetables; and a direct connection with personalized, preventive, and functional nutrition. As such, this cluster articulates one of the most robust dimensions of the “healthy and sustainable” approach by linking the design of functional foods with scientific evidence of physiological impact in humans (see Figure 3B).

The search for nutritional solutions to reduce the incidence of metabolic and cardiovascular diseases has driven the investigation of functional compounds and their clinical applications. This cluster compiles scientific evidence on the positive impact of specific nutrients and functional foods in the regulation of risk markers, particularly those associated with inflammation, lipid profiles, and blood glucose levels [11], [50]. The integration of these compounds into therapeutic diets has become a preventive and complementary strategy in clinical practice.

Omega-3 fatty acids, polyphenols, and phytosterols are among the most extensively studied compounds due to their ability to modulate inflammatory responses, reduce LDL cholesterol, and improve insulin sensitivity. Moreover, evidence of their protective effects against endothelial dysfunction and oxidative stress has been pivotal in supporting their inclusion in functional supplements and fortified foods [52], [53].

From a clinical perspective, several trials have confirmed the efficacy of these compounds in populations at cardiovascular risk, demonstrating significant improvements in blood pressure, triglyceride levels, and fasting glucose following controlled interventions [54], [55]. In some cases, a positive interaction with pharmacological treatments has been observed, opening the possibility for combined strategies that enhance therapeutic effects [56], [57].

Moreover, studies on fermented foods and gut microbiota highlight the importance of probiotics and prebiotics in the prevention of metabolic diseases by influencing energy metabolism regulation, chronic inflammation, and lipid homeostasis. These findings reinforce the notion that a diet rich in bioactive compounds can play a key role in primary prevention, particularly in individuals with a family history or modifiable risk factors [58], [59].

Ultimately, this cluster underscores an integrative approach where nutrition, genetics, and preventive medicine converge to address current challenges in metabolic health. The application of functional compounds represents not only a viable therapeutic alternative but also an educational tool to promote sustainable and clinically effective dietary habits.

Cluster 3: Personalized Nutrition, Microbiota, and Dietary Patterns in the Prevention of Chronic Diseases
This cluster reflects a comprehensive and highly interdisciplinary approach that encompasses: precision nutrition grounded in genetic and epigenetic factors, applied to the prevention and treatment of chronic diseases such as cancer, cardiovascular conditions, and inflammatory disorders of the digestive tract; the study of therapeutic dietary patterns and their long-term health risks and benefits; the modulation of the gut–brain–immune axis through the intestinal microbiota and natural functional foods; and the integration of emerging concepts such as chrononutrition, nutritional exposomics, and food risk management. This cluster represents a key node in the transition toward healthy, sustainable, and biologically personalized nutrition, positioning it as a research priority in current nutrigenomics and food engineering studies (see Figure 3C).

Over the past decade, research in health and nutrition has advanced significantly toward more individualized approaches, in which the interaction between diet, gut microbiota, and an individual’s genetic profile plays a decisive role in the prevention of chronic diseases. This bibliometric cluster reflects a thematic convergence that underscores the need to understand how dietary patterns, tailored to personal characteristics, can modulate key physiological processes involved in the prevention of metabolic, cardiovascular, and immunological disorders. Personalized nutrition is emerging as an effective alternative by considering not only genetic and epigenetic variables but also the microbial composition of the gut, thereby enabling the design of targeted dietary interventions for different risk phenotypes [21], [24].

The studies included in this cluster address both the identification of biomarkers and the characterization of healthy dietary patterns, such as the Mediterranean diet and its anti-inflammatory and cardioprotective effects [60]. In addition, this cluster explores how gut microbial diversity responds to different nutritional intakes and how these responses may influence the onset or mitigation of chronic diseases such as type 2 diabetes, obesity, and cardiovascular disorders [56]. Research also explores the implications of diet on immune function through the modulation of microbial metabolites, such as short-chain fatty acids [15], which act as mediators between the gut and peripheral organs.

Another recurring theme in the studies within this cluster is the impact of the food environment and lifestyle factors on gene expression related to energy metabolism and systemic inflammation. Within this framework, a more comprehensive understanding of prevention is promoted, highlighting the need to incorporate omics technologies into the design of dietary programs tailored to specific populations and ethnic groups. Ultimately, this cluster underscores the importance of public policies that promote diversified, culturally adapted, and evidence-based nutrition as part of a public health strategy aimed at sustainability and nutritional equity [55], [61].

Cluster 4: Personalized Nutrition, Pharmacotherapy, and Precision Medicine in the Management of Obesity and Metabolic Disorders

This cluster represents the clinical-therapeutic core of scientific output related to healthy and sustainable nutrition. Its central focus is medical and pharmacological intervention in obesity, supported by: next-generation drugs and therapeutic cocktails validated through rigorous clinical trials; the implementation of personalized medicine and pharmacogenetic approaches to tailor treatments to individual metabolic profiles; the consideration of behavioral, physiological, and lifestyle factors in combating metabolic diseases; and the integration of individualized nutrition and scientifically grounded dietotherapy. This cluster illustrates how the boundaries between nutrition, medicine, and biotechnology are increasingly blurred in the pursuit of sustainable and effective solutions to one of the most pressing global public health challenges: obesity and its comorbidities (see Figure 3D).

The integration of personalized nutrition with pharmacotherapy and precision medicine constitutes one of the most promising strategies for the clinical management of obesity and metabolic disorders. This approach acknowledges that responses to nutritional and pharmacological treatments vary significantly among individuals due to genetic, epigenetic, metabolic, and microbiome-related factors. In this context, the incorporation of omics technologies has enabled the identification of predictive biomarkers of risk and treatment response, facilitating the personalization of diets and medications based on individual patient characteristics [62].

Several studies have demonstrated that specific genetic polymorphisms can influence the efficacy of bioactive compounds in weight control and lipid metabolism, opening the door to the implementation of precision nutritional plans in which nutrients and functional foods are selected based on an individual’s genetic makeup [24]. At the same time, pharmacotherapy for obesity has seen significant advances with the development of drugs targeting specific pathways involved in appetite and satiety, featuring more tolerable safety profiles and the potential to be combined with personalized nutritional interventions [63].

On the other hand, the role of the gut microbiome is highlighted as a modulator of the metabolic response to both diet and pharmacological treatments, positioning the microbiota as a key therapeutic target in precision medicine [56].. Moreover, the use of artificial intelligence and machine learning platforms has begun to support the prediction of optimal diet–drug combinations based on the patient’s clinical profile [55]

Finally, this cluster reveals a clear trend toward an integrative and personalized therapeutic model aimed at maximizing the efficacy of obesity interventions through the synergy of precision nutrition, targeted pharmacotherapy, and emerging technologies for individualized analysis.

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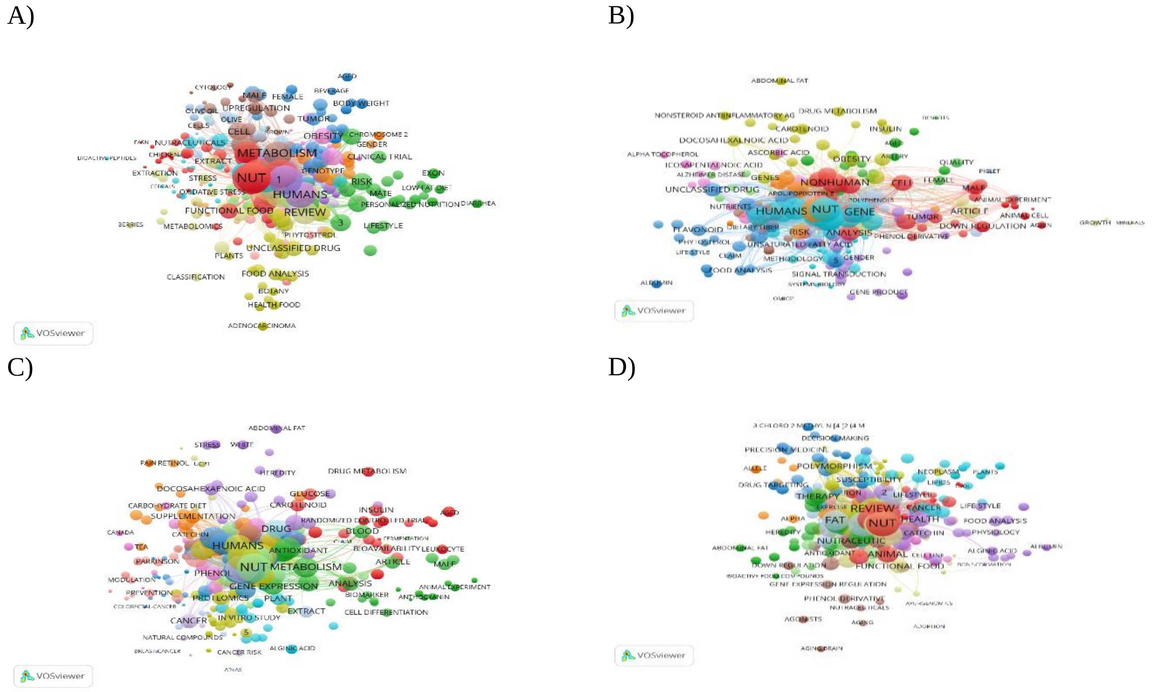
Figure 3. Clústeres



CONCLUSION

A comprehensive analysis of scientific output in the fields of nutrigenomics, functional foods, and food engineering reveals a profound transformation in the conception of nutrition as a central axis connecting health, sustainability, and technology. Based on bibliometric analysis and co-occurrence network mapping, it is evident that these fields have evolved from fragmented areas into an integrated knowledge system that promotes personalized, preventive, and environmentally responsible nutrition. The four identified clusters reflect well-established thematic lines ranging from the molecular exploration of bioactives and their technological applications to targeted clinical interventions and the synergy between personalized nutrition and pharmacotherapy in the treatment of metabolic disorders.

In this context, the application of omics technologies, food process engineering, predictive modeling through artificial intelligence, and the growing integration of the microbiome are enabling the development of precise, culturally adapted nutritional strategies with demonstrable impacts on health biomarkers. Moreover, the PRISMA methodology has proven essential for validating, organizing, and prioritizing emerging scientific evidence, while bibliometric analysis has facilitated the identification of trends, gaps, and opportunities for collaborative innovation.

However, the advancement of this new paradigm also brings significant challenges, particularly concerning equitable access to genetic technologies, the protection of personal data, the clinical validation of dietary interventions, and the implementation of public policies that align these advances with the goals of the Sustainable Development Goals (SDGs). The consolidation of a truly resilient and sustainable food system therefore requires not only scientific and technological innovation, but also participatory governance that ensures food justice, cultural respect, and ecological sustainability. The co-evolution of science, society, and public health will be essential in shaping a future of nutrition that is simultaneously healthy, intelligent, and inclusive.

REFERENCES

1. A. Fardet, «New hypotheses for the health-protective mechanisms of whole-grain cereals: what is beyond fibre?», NUTRITION RESEARCH REVIEWS, vol. 23, n.o 1. CAMBRIDGE UNIV PRESS, EDINBURGH BLDG, SHAFTESBURY RD, CB2 8RU CAMBRIDGE, ENGLAND, pp. 65-134, junio de 2010. doi: 10.1017/S0954422410000041.

2. A. Masotti, L. Da Sacco, G. F. Bottazzo, y A. Alisi, «Microarray Technology: A Promising Tool in Nutrigenomics», CRITICAL REVIEWS IN FOOD SCIENCE AND NUTRITION, vol. 50, n.o 7. TAYLOR & FRANCIS INC, 530 WALNUT STREET, STE 850, PHILADELPHIA, PA 19106 USA, pp. 693-698, 2010. doi: 10.1080/10408390903044156.
3. H. N. Lam et al., «Integrative Roles of Functional Foods, Microbiotics, Nutrigenetics, and Nutrigenomics in Managing Type 2 Diabetes and Obesity», NUTRIENTS, vol. 17, n.o 4. MDPI, MDPI AG, Grosspeteranlage 5, CH-4052 BASEL, SWITZERLAND, febrero de 2025. doi: 10.3390/nu17040608.
4. D. Chaudhary et al., «Nutrigenomics and personalized diets - Tailoring nutrition for optimal health», Applied Food Research, vol. 5, n.o 1. 2025. doi: 10.1016/j.afres.2025.100980.
5. H. Berisha, R. Hattab, L. Comi, C. Giglione, S. Migliaccio, y P. Magni, «Nutrition and Lifestyle Interventions in Managing Dyslipidemia and Cardiometabolic Risk», NUTRIENTS, vol. 17, n.o 5. MDPI, MDPI AG, Grosspeteranlage 5, CH-4052 BASEL, SWITZERLAND, marzo de 2025. doi: 10.3390/nu17050776.
6. A. Arsalan et al., «Nutrigenomic Potential of Mineral Nano-Particles to Modulate Poultry Health and Performance», Journal of Animal Physiology and Animal Nutrition, vol. 109, n.o 4. pp. 1048-1061, 2025. doi: 10.1111/jpn.14119.
7. M. E. Abd El-Hack et al., «Beyond traditional uses: Unveiling the epigenetic, microbiome-modulating, metabolic, and nutraceutical benefits of Salvia officinalis in human and livestock nutrition», JOURNAL OF FUNCTIONAL FOODS, vol. 128. ELSEVIER, RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS, mayo de 2025. doi: 10.1016/j.jff.2025.106843.
8. M. E. Abd El-Hack et al., «Nutritional value and therapeutic applications of Chenopodium album for human and livestock health: A comprehensive review», FOOD BIOSCIENCE, vol. 68. ELSEVIER, RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS, junio de 2025. doi: 10.1016/j.fbio.2025.106624.
9. K. Petroni, R. Pilu, y C. Tonelli, «Anthocyanins in corn: a wealth of genes for human health», Planta, vol. 240, n.o 5. pp. 901-911, 2014. doi: 10.1007/s00425-014-2131-1.
10. A. Vesnina, A. Prosekov, V. Atuchin, V. Minina, y A. Ponasenko, «Tackling Atherosclerosis via Selected Nutrition», International Journal of Molecular Sciences, vol. 23, n.o 15. 2022. doi: 10.3390/ijms23158233.
11. S. Sgorlon, B. Stefanon, M. Sandri, y M. Colitti, «Nutrigenomic activity of plant derived compounds in health and disease: Results of a dietary intervention study in dog», Research in Veterinary Science, vol. 109. pp. 142-148, 2016. doi: 10.1016/j.rvsc.2016.10.005.
12. B. Bayram et al., «Breakthroughs in the Health Effects of Plant Food Bioactives: A Perspective on Microbiomics, Nutri(epi)genomics, and Metabolomics», Journal of Agricultural and Food Chemistry, vol. 66, n.o 41. pp. 10686-10692, 2018. doi: 10.1021/acs.jafc.8b03385.
13. S. R. B. M. Eussen et al., «Functional foods and dietary supplements: Products at the interface between pharma and nutrition», EUROPEAN JOURNAL OF PHARMACOLOGY, vol. 668, n.o 1. ELSEVIER, RADARWEG 29, 1043 NX AMSTERDAM, NETHERLANDS, pp. S2-S9, septiembre de 2011. doi: 10.1016/j.ejphar.2011.07.008.
14. M. L. De Marchis et al., «Genetic bases of the nutritional approach to migraine», CRITICAL REVIEWS IN FOOD SCIENCE AND NUTRITION, vol. 59, n.o 14. TAYLOR & FRANCIS INC, 530

WALNUT STREET, STE 850, PHILADELPHIA, PA 19106 USA, pp. 2308-2320, 6 de agosto de 2019. doi: 10.1080/10408398.2018.1450215.

15. T. C. Rideout, «Getting personal: Considering variable interindividual responsiveness to dietary lipid-lowering therapies», Current Opinion in Lipidology, vol. 22, n.o 1. pp. 37-42, 2011. doi: 10.1097/MOL.0b013e3283414e71.
16. B. J. Bradford, K. Yuan, y C. Ylioja, «Managing complexity: Dealing with systemic crosstalk in bovine physiology», Journal of Dairy Science, vol. 99, n.o 6. pp. 4983-4996, 2016. doi: 10.3168/jds.2015-10271.
17. A. Palou, M. L. Bonet, y C. Pico, «On the role and fate of sugars in human nutrition and health. Introduction», OBESITY REVIEWS, vol. 10. WILEY-BLACKWELL PUBLISHING, INC, COMMERCE PLACE, 350 MAIN ST, MALDEN 02148, MA USA, pp. 1-8, marzo de 2009. doi: 10.1111/j.1467-789X.2008.00560.x.
18. F. Visioli, «Can experimental pharmacology be always applied to human nutrition?», International Journal of Food Sciences and Nutrition, vol. 63, n.o SUPPL. 1. pp. 10-13, 2012. doi: 10.3109/09637486.2012.665439.
19. M. Gomez de Cedron, L. Mouhid, E. Garcia-Carrascosa, T. Fornari, G. Reglero, y A. Ramirez de Molina, «Marigold Supercritical Extract as Potential Co-adjuvant in Pancreatic Cancer: The Energetic Catastrophe Induced via BMP8B Ends Up With Autophagy-Induced Cell Death», FRONTIERS IN BIOENGINEERING AND BIOTECHNOLOGY, vol. 7. FRONTIERS MEDIA SA, AVENUE DU TRIBUNAL FEDERAL 34, LAUSANNE, CH-1015, SWITZERLAND, 24 de enero de 2020. doi: 10.3389/fbioe.2019.00455.
20. M.-A. Verny et al., «Evaluating the role of orange juice, HESPERidin in vascular HEALTH benefits (HESPER-HEALTH study): Protocol for a randomised controlled trial», BMJ Open, vol. 11, n.o 11. 2021. doi: 10.1136/bmjopen-2021-053321.
21. G. Flore, A. Deledda, M. Lombardo, A. Armani, y F. Velluzzi, «Effects of Functional and Nutraceutical Foods in the Context of the Mediterranean Diet in Patients Diagnosed with Breast Cancer», Antioxidants, vol. 12, n.o 10. 2023. doi: 10.3390/antiox12101845.
22. T. Ruskovska, C. Morand, C. I. Bonetti, K. S. Gebara, E. L. Cardozo Junior, y D. Milenkovic, «Multigenomic modifications in human circulating immune cells in response to consumption of polyphenol-rich extract of yerba mate (Ilex paraguariensis A. St.-Hil.) are suggestive of cardiometabolic protective effects», BRITISH JOURNAL OF NUTRITION, vol. 129, n.o 2. CAMBRIDGE UNIV PRESS, EDINBURGH BLDG, SHAFTESBURY RD, CB2 8RU CAMBRIDGE, ENGLAND, pp. 185-205, 28 de enero de 2023. doi: 10.1017/S0007114522001027.
23. S. Maiti y A. Banik, «Strategies to fortify the nutritional values of polished rice by implanting selective traits from brown rice: A nutrigenomics-based approach», Food Research International, vol. 173. 2023. doi: 10.1016/j.foodres.2023.113271.
24. P. M. Coates et al., «The Evolution of Science and Regulation of Dietary Supplements: Past, Present, and Future», Journal of Nutrition, vol. 154, n.o 8. pp. 2335-2345, 2024. doi: 10.1016/j.tjnut.2024.06.017.
25. B. Reynés, T. Priego, M. Cifre, P. Oliver, y A. Palou, «Peripheral Blood Cells, a Transcriptomic Tool in Nutrigenomic and Obesity Studies: Current State of the Art», Comprehensive Reviews

in Food Science and Food Safety, vol. 17, n.o 4. pp. 1006-1020, 2018. doi: 10.1111/1541-4337.12363.
26. Y. E. Pérez-Beltrán et al., «Personalized Dietary Recommendations Based on Lipid-Related Genetic Variants: A Systematic Review», Frontiers in Nutrition, vol. 9. 2022. doi: 10.3389/fnut.2022.830283.
27. Y. E. Pérez-Beltrán et al., «Personalized Dietary Recommendations Based on Lipid-Related Genetic Variants: A Systematic Review», Frontiers in Nutrition, vol. 9. 2022. doi: 10.3389/fnut.2022.830283.
28. E. Sharma et al., «Edible mushrooms trending in food: Nutrigenomics, bibliometric, from bench to valuable applications», Heliyon, vol. 10, n.o 17. 2024. doi: 10.1016/j.heliyon.2024.e36963.
29. Y. Li et al., «Emerging trends and hotspots in the links between the gut microbiota and MAFLD from 2002 to 2021: A bibliometric analysis», Frontiers in Endocrinology, vol. 13. 2022. doi: 10.3389/fendo.2022.990953.
30. R. Devi et al., «Non-dairy prebiotics: Conceptual relevance with nutrigenomics and mechanistic understanding of the effects on human health», Food Research International, vol. 170. 2023. doi: 10.1016/j.foodres.2023.112980.
31. D. Dutta et al., «Predictors of quality of life in people living with type-1 and type-2 diabetes: an Indian perspective study and systematic review», Clinical Diabetology, vol. 11, n.o 1. pp. 33-44, 2022. doi: 10.5603/DK.a2021.0057.
32. M. Su, H. Wei, L. Chen, Y. Guan, W. Dong, y M. Zhao, «The Impact of Visceral Adiposity on Testosterone Levels in American Adult Men: A Cross-Sectional Analysis», Medical Science Monitor, vol. 29. 2023. doi: 10.12659/MSM.941394.
33. G. Zheng et al., «Sugar types, genetic predictors of the gut microbiome, and the risk of chronic kidney disease: a prospective cohort study», Food and Function, vol. 15, n.o 9. pp. 4925-4935, 2024. doi: 10.1039/d4fo00724g.
34. M. Ruiz y E. Garcia, «Optimizing Power Quality Signal Compression: Harnessing Compressed Sensing and Reconstruction Techniques for Big Data Measurement», IEEE Access, vol. 13. pp. 36339-36347, 2025. doi: 10.1109/ACCESS.2025.3544147.
35. X. Wu, Z. Wang, X. Liao, y Y.-Y. Wang, «Three oral Chinese patent medicines for children with tic disorder: a rapid health technology assessment; [3 种口服中成药治疗儿童抽动障碍的快速卫生技术评估]», Zhongguo Zhongyao Zazhi, vol. 48, n.o 14. pp. 3965-3976, 2023. doi: 10.19540/j.cnki.cjcmm.20230330.502.
36. R. De Almeida, M. C. Doska, J. A. Horst, A. A. Valloto, G. T. D. Santos, y L. S. De Lima, «Associations of days open with milk urea nitrogen and other herd traits in dairy cows», Revista Brasileira de Zootecnia, vol. 50. pp. 1-9, 2021. doi: 10.37496/RBZ5020200081.
37. S.-Y. Lee, J. Wang, H.-B. Tsai, C.-T. Chao, K.-L. Chien, y J.-W. Huang, «Muscle relaxant use and the associated risk of incident frailty in patients with diabetic kidney disease: a longitudinal cohort study», Therapeutic Advances in Drug Safety, vol. 12. 2021. doi: 10.1177/20420986211014639.

38. L. Kang, W. Wang, T. Feng, T. Cui, y S. Wang, «Exploration of strategies for improving clinical research level in medical universities: analysis and practice of clinical research in Shanghai Jiao Tong University School of Medicine; [医学院校临床研究水平提升的策略探讨——上海交通大学医学院临床研究的现状分析与实践探索]», Journal of Shanghai Jiaotong University (Medical Science), vol. 44, n.o 9. pp. 1197-1204, 2024. doi: 10.3969/j.issn.1674-8115.2024.09.015.
39. A. Bayés-Genís et al., «Soluble neprilysin is predictive of cardiovascular death and heart failure hospitalization in heart failure patients», Journal of the American College of Cardiology, vol. 65, n.o 7. pp. 657-665, 2015. doi: 10.1016/j.jacc.2014.11.048.
40. H. J. Kim et al., «Impact of Valve Replacement on Long-Term Survival in Asymptomatic Patients With Severe Aortic Stenosis», American Journal of Cardiology, vol. 123, n.o 8. pp. 1321-1328, 2019. doi: 10.1016/j.amjcard.2019.01.035.
41. E. M. Ramos-Dávila et al., «Underrepresentation of Low-and Middle-Income Nations in Ophthalmology Journals: A Critical Analysis on Diversity, Equity, and Global Representation», Translational Vision Science and Technology, vol. 12, n.o 10. 2023. doi: 10.1167/tvst.12.10.9.
42. Y. Kanakubo et al., «Association between person-centred care quality and advance care planning participation in haemodialysis», BMJ Supportive and Palliative Care, vol. 14, n.o e3. pp. e2872-e2879, 2024. doi: 10.1136/spcare-2024-004831.
43. R. Lee et al., «Late neurologic events after surgery for atrial fibrillation: Rare but relevant», Annals of Thoracic Surgery, vol. 95, n.o 1. pp. 126-132, 2013. doi: 10.1016/j.athoracsur.2012.08.048.
44. Y. Zhu, J. Xu, X. Zhang, Y. Ke, G. Fu, y Q. Guo, «A low follicle-stimulating hormone level is a protective factor for non-alcoholic fatty liver disease in older men aged over 80», BMC Geriatrics, vol. 21, n.o 1. 2021. doi: 10.1186/s12877-021-02490-6.
45. Q. Wu et al., «Relationship of several serum folate forms with the prevalence of hypertension», Precision Nutrition, vol. 2, n.o 4. 2023. doi: 10.1097/PN9.0000000000000058.
46. R. Peacock, M. Bently, P. Rees, y J. N. Blignaut, «The benefits of ecological restoration exceed its cost in South Africa: An evidence-based approach», Ecosystem Services, vol. 61. 2023. doi: 10.1016/j.ecoser.2023.101528.
47. J. Feng, J. P. Iser, y W. Yang, «Medical encounters for opioid-related intoxications in Southern Nevada: Sociodemographic and clinical correlates», BMC Health Services Research, vol. 16, n.o 1. 2016. doi: 10.1186/s12913-016-1692-z.
48. J. M. Sánchez-Jaramillo, L. C. Domínguez, N. V. Vega, y P. Meneses, «The state of research in general surgery education in colombia (2000-2020): A bibliometric analysis; [El estado de la investigación en educación en cirugía general en colombia (2000-2020): un análisis bibliométrico]», Revista Colombiana de Cirugia, vol. 36, n.o 2. pp. 205-220, 2021. doi: 10.30944/20117582.702.
49. R. Erro, F. Brigo, S. Tamburin, M. Zamboni, A. Antonini, y M. Tinazzi, «Nutritional habits, risk, and progression of Parkinson disease», Journal of Neurology, vol. 265, n.o 1. pp. 12-23, 2018. doi: 10.1007/s00415-017-8639-0.

50. A. Mortensen et al., «Biological models for phytochemical research: From cell to human organism», British Journal of Nutrition, vol. 99, n.o E-SUPPL. 1. pp. ES118-ES126, 2008. doi: 10.1017/S0007114508965806.
51. C. Luceri, E. Bigagli, V. Pitozzi, y L. Giovannelli, «A nutrigenomics approach for the study of anti-aging interventions: olive oil phenols and the modulation of gene and microRNA expression profiles in mouse brain», European Journal of Nutrition, vol. 56, n.o 2. pp. 865-877, 2017. doi: 10.1007/s00394-015-1134-4.
52. L. Corzo et al., «Nutrition, health, and disease: Role of selected marine and vegetal nutraceuticals», Nutrients, vol. 12, n.o 3. 2020. doi: 10.3390/nu12030747.
53. U. N. Mishra et al., «Nutrigenomics: An inimitable interaction amid genomics, nutrition and health», Innovative Food Science and Emerging Technologies, vol. 82. 2022. doi: 10.1016/j.ifset.2022.103196.
54. M. Herrero, C. Simõ, V. García-Cañas, E. Ibáñez, y A. Cifuentes, «Foodomics: MS-based strategies in modern food science and nutrition», Mass Spectrometry Reviews, vol. 31, n.o 1. pp. 49-69, 2012. doi: 10.1002/mas.20335.
55. M. T. R. Subbiah, «Nutrigenetics and nutraceuticals: the next wave riding on personalized medicine», Translational Research, vol. 149, n.o 2. pp. 55-61, 2007. doi: 10.1016/j.trsl.2006.09.003.
56. [56]G. Panagiotou y J. Nielsen, «Nutritional systems biology: Definitions and approaches», Annual Review of Nutrition, vol. 29. pp. 329-339, 2009. doi: 10.1146/annurev-nutr-080508-141138.
57. S. Srivastava et al., «Emergence of nutrigenomics and dietary components as a complementary therapy in cancer prevention», Environmental Science and Pollution Research, vol. 29, n.o 60. pp. 89853-89873, 2022. doi: 10.1007/s11356-022-24045-x.
58. J. C. E. Serrano, M. Jove, H. Gonzalo, R. Pamplona, y M. Portero-Otin, «Nutridynamics: Mechanism(s) of action of bioactive compounds and their effects», International Journal of Food Sciences and Nutrition, vol. 66. pp. S22-S30, 2015. doi: 10.3109/09637486.2015.1035231.
59. S. Saleem et al., «Millets as smart future food with essential phytonutrients for promoting health», Journal of Food Composition and Analysis, vol. 124. 2023. doi: 10.1016/j.jfca.2023.105669.
60. R. A. Mir et al., «Utilizing the underutilized plant resources for development of life style foods: Putting nutrigenomics to use», Plant Physiology and Biochemistry, vol. 171. pp. 128-138, 2022. doi: 10.1016/j.plaphy.2021.12.038.
61. K. Swanson et al., «Bovine milk consumption affects the transcriptome of porcine adipose stem cells: Do exosomes play any role?», PLoS ONE, vol. 19, n.o 12 December. 2024. doi: 10.1371/journal.pone.0302702.
62. M. L. Bonet, J. Mercader, y A. Palou, «A nutritional perspective on UCP1-dependent thermogenesis», Biochimie, vol. 134. pp. 99-117, 2017. doi: 10.1016/j.biochi.2016.12.014.
63. M. A. Gammone y N. D'Orazio, «Anti-obesity activity of the marine carotenoid fucoxanthin», Marine Drugs, vol. 13, n.o 4. pp. 2196-2214, 2015. doi: 10.3390/md13042196.