

Mapping the Patent Landscape of Fermented Food Innovations for Gut Health: Technology Gaps, White Spaces, and Innovation Pathways

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ABSTRACT

Fermented foods represent promising platforms for gut-health innovation because of their microbial diversity, bioactive components, and functional properties. However, the technological landscape remains unevenly developed, with limited understanding of innovation trajectories, concentrations, gaps, and emerging white spaces. This study mapped the patent landscape of fermented food innovations targeting gut health, identified innovation gaps and white spaces, and developed an evidence-informed innovation pathways framework. Patent records were retrieved from the Lens database, where 23,004 initial records were refined to 1,163 records, further screened to 336 documents, and consolidated into 189 patent families. Twelve analytical dimensions were examined, including temporal trends, jurisdictions, technological classifications, innovation actors, citation patterns, and legal status. Results revealed an expanding and multidisciplinary innovation landscape but substantial technological concentration around conventional dairy-based and probiotic-centered systems, particularly *Lactobacillus* and *Lactobacteriaceae* pathways, selected jurisdictions, and established innovation actors. Integrated analysis identified ten interconnected gaps and white spaces encompassing alternative food matrices, localized fermentation resources, novel microbial strains and consortia, plant-based and non-dairy products, postbiotics, targeted gut-health mechanisms, emerging geographic systems, less concentrated ownership niches, inactive or expired patents, and interdisciplinary innovation networks. These findings informed the GAP-TO-GROWTH Innovation Pathways Framework, which translates patent intelligence into strategic solutions, implementation pathways, and innovation outcomes. Overall, the study advances patent landscape analysis beyond descriptive mapping by providing a solution-oriented framework for research prioritization, technological differentiation, intellectual property development, commercialization, and sustainable fermented food innovation for gut health.

Keywords: Patent landscape analysis; Gap-to-Growth Innovation Pathways Framework; Patent families; Probiotics; Intellectual property

INTRODUCTION

The increasing global burden of gastrointestinal disorders, metabolic diseases, and other diet-related health conditions has intensified scientific and technological interest in the gut microbiome and its relationship with human health. The gastrointestinal microbiome is increasingly recognized as an important component of host physiology, influencing metabolic processes, immune function, intestinal homeostasis, and interactions between diet and health. Among the modifiable determinants of the gut microbial ecosystem, diet has received particular attention because dietary components can influence microbial composition, metabolic activity, and host-microbe interactions. Consequently, there is growing interest in food-based strategies that may support gastrointestinal health and contribute to healthier dietary environments. Patent landscape analyses have likewise demonstrated the value of patent databases for mapping technological development, identifying key contributors, and examining emerging innovation patterns across health-related technologies (Gudelos, 2025a, 2025b).

Within this context, fermented foods have emerged as an important area of research and innovation. Fermented foods and beverages are broadly defined as foods produced through desired microbial growth and enzymatic conversions of food components (Marco et al., 2021). Their biological and technological complexity arises from the interaction of microorganisms, food substrates, and fermentation-derived metabolites, which may collectively influence gastrointestinal processes and other aspects of human health. Recent evidence suggests that fermented foods can provide a unique combination of microorganisms and bioactive compounds with potential relevance to gastrointestinal health, including effects associated with microbial exposure, food matrix transformation, metabolite production, and improved digestibility (Mukherjee et al., 2024).

However, the growing interest in fermented foods should not obscure important distinctions between fermented foods and probiotics. Although some fermented foods contain viable microorganisms, fermented foods do not automatically qualify as probiotic foods. Probiotics are defined as live microorganisms that, when administered in adequate amounts, confer a health benefit on the host, whereas fermented foods are not required to contain microorganisms characterized at the strain level or to demonstrate a specific health benefit (Hill et al., 2014; Marco et al., 2021). This distinction is particularly important for research and innovation because the development of fermented foods targeting gut health requires scientific consideration not only of microbial content but also of the food matrix, fermentation processes, metabolites, mechanisms of action, product functionality, safety, and substantiation of health-related claims. Consistent with previous patent landscape work, technological mapping can complement conventional scientific evidence by revealing how research-related concepts are translated into patentable technologies and how innovation activity is distributed among different contributors and technological domains (Gudelos, 2025a, 2025b).

The expanding scientific interest in the relationship between fermented foods and gut health has also generated opportunities for technological development. Fermentation is increasingly being explored not merely as a traditional food preservation technique but as a platform for developing value-added foods with enhanced nutritional, functional, and health-related properties. Advances in microbiology, metabolomics, food biotechnology, and microbiome science have further expanded the potential for designing fermented food products that address specific consumer and health-related needs. Nevertheless, Mukherjee et al. (2024) emphasized that the mechanisms through which fermented foods influence gastrointestinal health remain incompletely understood and that additional well-designed human studies are needed to substantiate specific health effects. Against this background, patent landscape analysis provides a complementary approach for examining the technological response to this emerging scientific field, including patterns of patent activity, technological concentration, and the organizations and individuals contributing to innovation.

Despite the growing body of scientific literature, much of the existing knowledge on fermented foods and gut health remains concentrated on biological mechanisms, microbial characteristics, nutritional properties, and clinical or health-related outcomes. Comparatively less attention has been directed toward understanding how scientific knowledge in this field is translated into technological inventions and protected intellectual property. This represents an important knowledge gap because scientific publications and patent documents provide complementary perspectives on technological development. While scientific literature primarily documents the generation and dissemination of knowledge, patent records can provide evidence of inventions, technological trajectories, innovation actors, geographical activity, and areas targeted for commercialization or intellectual property protection. Patent data have therefore been widely recognized as useful indicators for examining technological development and innovation activity (Grant et al., 2014).

A systematic examination of the patent landscape can consequently provide insights that are not readily obtained from conventional literature reviews. Patent landscape analysis can reveal the temporal evolution of technological activity, geographic and institutional concentrations, dominant technological domains, leading applicants and inventors, influential inventions, and emerging areas of technological specialization. Importantly, patent intelligence may also help identify technological gaps and innovation white spaces—areas where scientific potential, market opportunities, or available resources may not yet be adequately reflected in existing technological development. Such information is particularly relevant for countries and regions with diverse agricultural resources, indigenous food materials, and longstanding fermentation

traditions, where underutilized biological and food resources may offer opportunities for future value-added innovation.

This perspective is especially relevant to the Philippine context. The country possesses substantial agricultural biodiversity and diverse traditional food fermentation practices that could potentially serve as resources for functional food development and innovation. However, the translation of indigenous food resources and traditional fermentation knowledge into scientifically substantiated, technologically differentiated, and intellectual-property-oriented innovations remains a continuing challenge. Understanding the global technological landscape of fermented food innovations targeting gut health may therefore provide strategic evidence for identifying opportunities relevant to local food systems, agricultural value addition, research commercialization, and innovation development.

The present study addresses this gap by moving beyond conventional discussions of the biological and health-related properties of fermented foods and examining the technological innovation landscape surrounding fermented foods targeting gut health. Specifically, the study employs a patent landscape approach to investigate patterns of technological development, intellectual property activity, innovation actors, technological classifications, influential patents, and potential gaps within the field. By integrating patent intelligence with technology-gap and white-space analysis, the study seeks to generate a more forward-looking understanding of where fermented food innovation for gut health has developed and where opportunities for future technological advancement may exist.

The principal contribution of the study is the development of an Innovation Pathways Framework for Fermented Food Innovations Targeting Gut Health. Rather than limiting the analysis to descriptive patent mapping, the framework translates observed technological trends, gaps, and innovation white spaces into potential strategic directions for future research and development. The proposed framework is intended to support researchers, food technologists, innovators, entrepreneurs, industry stakeholders, and policymakers in identifying promising pathways for product development, technology advancement, commercialization, and intellectual property protection.

The study also has broader relevance to sustainable food systems and community development. By identifying potential pathways for the development and value addition of fermented food resources, the study contributes conceptually to efforts related to food innovation, healthier dietary environments, industrial and technological development, and the sustainable utilization of food resources. In this regard, its potential implications align with Sustainable Development Goal (SDG) 2 on Zero Hunger, SDG 3 on Good Health and Well-Being, SDG 9 on Industry, Innovation and Infrastructure, and SDG 12 on Responsible Consumption and Production.

Accordingly, this study aimed to map the global patent landscape of fermented food innovations targeting gut health and translate patent intelligence into future innovation pathways. Specifically, it sought to: (1) examine the temporal evolution of patent activity related to fermented food innovations targeting gut health; (2) analyze the geographic distribution and document characteristics of identified patent records; (3) identify dominant technological domains using Cooperative Patent Classification (CPC) and International Patent Classification (IPC) codes; (4) determine key innovation actors, including major applicants, owners, inventors, and relevant intellectual property representatives; (5) assess influential patents and technological areas through citation-related and legal-status analyses; (6) identify technology gaps and innovation white spaces within the existing patent landscape; and (7) develop an Innovation Pathways Framework that translates identified technological gaps and white spaces into strategic solutions and actionable pathways for advancing fermented food innovations targeting gut health.

To accomplish these objectives, the paper is designed as a patent landscape and technology intelligence study. The analysis systematically examines patent records using temporal, geographic, technological, actor-based, citation-related, and legal-status indicators. The resulting evidence is subsequently synthesized through technology-gap and innovation white-space analysis to inform the development of the proposed Innovation Pathways Framework. Through this approach, the study contributes not only to a descriptive

understanding of the existing intellectual property landscape but also to the identification of strategic directions for future fermented food innovation targeting gut health.

METHODS

Research Design

This study employed a descriptive patent landscape analysis to systematically map technological developments related to fermented food innovations for gut health. The analysis extended beyond the descriptive examination of patenting activity by identifying patterns in technological development, geographic distribution, innovation actors, patent classifications, and influential inventions. The resulting patent intelligence was subsequently examined to identify potential technology gaps and innovation white spaces, which served as the basis for developing an innovation pathways framework. The study followed a sequential analytical approach consisting of patent retrieval, dataset refinement, patent family consolidation, landscape mapping, gap and white-space identification, and framework development, consistent with the use of patent landscape analysis as a systematic approach for examining technological trends and informing research and innovation directions (van Rijn et al., 2023).

Data Source

Patent data were retrieved from the Lens patent database, a platform that provides access to global patent records and patent analytics. Lens was selected as the primary data source because it enables structured patent searching, Boolean query construction, filtering, patent-family grouping, and visualization of patent-related indicators. All patent records used in the analysis were obtained from the Lens database, and the final dataset was consolidated at the simple patent family level to reduce duplication resulting from multiple patent documents associated with related inventions across different jurisdictions. Although Lens provides broad international patent coverage, database-specific differences in language, indexing practices, metadata completeness, translation, and searchable patent content may influence the retrieval of relevant records, particularly for patents originating from non-English patent offices such as the China National Intellectual Property Administration (CNIPA) and the Japan Patent Office (JPO). Such differences may affect the sensitivity of keyword-based searches when relevant technological information is not consistently available in searchable English-language fields. Therefore, while the search strategy was designed to maximize retrieval using predefined keywords, Boolean combinations, and relevant synonyms, the dataset represents the patent records retrieved through the specified Lens search strategy rather than an exhaustive census of all potentially relevant patents worldwide.

Search Strategy

A staged search strategy was employed to progressively improve the specificity of the retrieved patent records. An initial broad search using the terms FERMENTED AND FOODS AND GUT AND HEALTH retrieved 23,004 records. The search was subsequently refined using a Boolean query designed to capture fermented food products and their relationship with gut health while excluding clearly unrelated technological fields. The refined search query was:

("fermented food" OR "fermented foods" OR "fermented beverage" OR "fermented product" OR "fermented plant-based food") AND ("gut health" OR "intestinal health" OR "gastrointestinal health" OR "digestive health" OR microbiome OR microbiota OR probiotic*) NOT (pharmaceutical OR drug OR animal OR livestock OR "animal feed" OR cosmetic OR fuel OR biofuel OR industrial)

The refined Boolean search retrieved 1,163 patent records. The search strategy was designed to capture innovations involving fermented foods and related products with applications associated with gastrointestinal health, digestive health, microbiota, microbiome, or probiotic functionality while reducing the retrieval of patents primarily related to non-food applications.

Eligibility Criteria (Inclusion and Exclusion Criteria)

Patent records were considered eligible when they demonstrated relevance to fermented food innovations associated with gut health or related gastrointestinal, microbiome, microbiota, digestive, or probiotic applications. Eligible records included inventions involving fermented foods, fermented beverages, fermented food products, and other food-based innovations in which fermentation was substantially connected with the identified health-related applications, whereas records primarily directed toward pharmaceuticals, drugs, animal or livestock applications, animal feed, cosmetics, fuel, biofuel, and other non-food industrial applications were excluded using predefined Boolean exclusion terms.

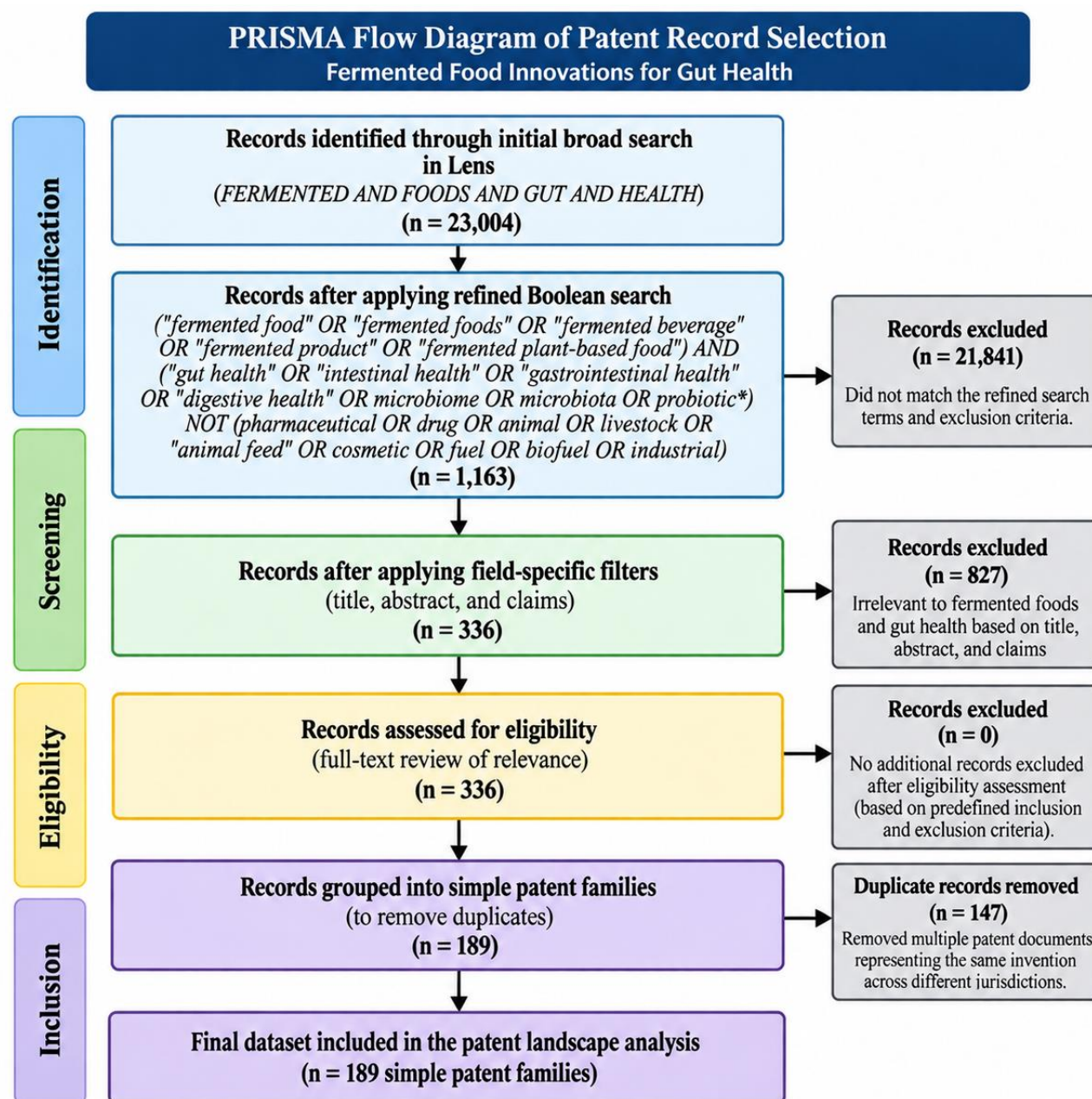
The exclusion of animal and livestock-related terms was applied to maintain the conceptual and technological scope of the landscape on human food and gut-health applications, recognizing that fermentation and microbial technologies frequently cross domains such as human foods, probiotics, animal health, and animal feed. Importantly, the animal/livestock exclusion was applied to the application context rather than to microorganisms themselves; microbial technologies, including probiotic microorganisms, bacterial strains, fermentation cultures, and microbial-derived products, remained eligible when their disclosed use was directed toward fermented foods or human gastrointestinal, microbiome, or gut-health applications, thereby systematically retaining relevant cross-over microbial technologies while excluding records whose primary application was animal health, livestock, or animal feed. Records with only incidental or secondary references to animals were retained when the principal technological application remained within the defined human-food and gut-health scope.

Because the study relied on the Lens patent database, retrieval was also subject to database-specific differences in language, indexing practices, metadata completeness, translation, and searchable patent content, particularly for records originating from non-English patent offices such as the China National Intellectual Property Administration (CNIPA) and the Japan Patent Office (JPO). Although the search strategy used predefined Boolean terms and relevant synonyms to maximize retrieval, such differences may affect the sensitivity of keyword-based searches; therefore, the resulting dataset represents the records retrieved through the specified Lens search strategy rather than an exhaustive census of all potentially relevant patents worldwide.

Data Filtering

Following the refined Boolean search, field-specific filters were applied to improve the substantive relevance of the retrieved records. Only patent records containing the relevant search information within the title, abstract, and claims were retained. This filtering process reduced the dataset from 1,163 to 336 patent records. The remaining records were subsequently grouped using the Simple Patent Family function in Lens to minimize duplication associated with multiple patent publications representing related inventions. This process resulted in a final dataset of 189 simple patent families, which constituted the analytical dataset for the patent landscape mapping.

The patent identification and selection process is summarized in the PRISMA-style flow diagram presented in Figure 1. The diagram provides a visual overview of the sequential stages used to identify, refine, screen, assess, and consolidate patent records for inclusion in the final patent landscape dataset. It complements the detailed description of the data source, search strategy, eligibility criteria, and data-filtering procedures presented above by showing how the records progressed through each stage of the selection process and how the final analytical dataset was established.



Note. Data and patent-selection procedures were derived from the Lens patent database. The PRISMA-style flow diagram was generated using AI assistance for illustrative purposes.

Figure 1. Patent Record Identification, Screening, and Inclusion for Fermented Food Innovations Targeting Gut Health

Patent Landscape Analysis

The final dataset of 189 simple patent families was analyzed using the patent analytics and visualization features available in Lens. The analysis examined multiple dimensions of the technological landscape, including patent documents over time, geographic distribution by jurisdiction, patent document types, dominant Cooperative Patent Classification (CPC) codes, and International Patent Classification (IPC) codes. The study also examined major innovation actors through analyses of top applicants, owners, inventors, agents and attorneys, and citation-related indicators, including top cited inventors, cited patent classifications, and influential patents according to legal status. Collectively, these indicators were used to characterize the evolution, technological composition, geographic concentration, ownership structure, and influence patterns within the field of fermented food innovations for gut health.

Data Presentation and Visualization

The results were presented through descriptive tables, figures, charts, and patent landscape visualizations

generated and extracted from Lens. Temporal trends were presented to illustrate changes in patent activity, while geographic visualizations were used to demonstrate the distribution of patent protection across jurisdictions. Classification-based charts were used to identify dominant technological domains, and applicant, owner, and inventor analyses were used to characterize the major actors contributing to innovation. Citation and legal-status analyses were used to provide additional insights into the influence and technological relevance of identified patent families. The visual outputs were subsequently interpreted in relation to broader patterns of technological development and innovation opportunities.

Patent Gaps and White Spaces

Patent gaps and innovation white spaces were identified through an integrative interpretation of the patent landscape findings. Areas showing high concentrations of patent activity were examined as dominant or established technological domains, whereas areas demonstrating limited representation, fragmented development, or apparent underexploration were considered potential opportunities for further innovation. The identification of gaps and white spaces was informed by the combined examination of temporal trends, technological classifications, patent jurisdictions, innovation actors, and citation patterns. Rather than relying solely on the absence of patents, the analysis considered the relative distribution and concentration of technological activity to identify potential areas where future research, product development, and intellectual property generation could be strategically directed.

Innovation Pathways Framework

An innovation pathways framework was developed based on the synthesis of findings from the patent landscape, technology gap, and white-space analyses. The framework was designed to translate patent intelligence into strategic directions for future fermented food innovation targeting gut health. It integrates insights regarding dominant technologies, emerging opportunities, underexplored areas, and potential innovation needs to guide subsequent research and development activities. The framework provides a conceptual pathway linking patent landscape evidence with potential directions for scientific investigation, product development, technological innovation, intellectual property generation, and commercialization. Through this final analytical stage, the study moves beyond descriptive patent mapping toward the development of a strategic and solution-oriented output for advancing innovation in fermented foods for gut health.

Ethical Considerations

This study adhered to the principles of research integrity, transparency, responsible scholarship, and respect for intellectual property. As the study exclusively analyzed publicly accessible patent records obtained from the Lens patent database, it involved no human participants, human biological specimens, animals, clinical data, or personally identifiable information; thus, informed consent and human-subject ethical approval were not required. Patent information was used solely for scholarly and analytical purposes, and the study makes no legal determination regarding patent validity, infringement, ownership, or freedom to operate. Methodological procedures, including the search strategy, eligibility criteria, data filtering, patent family consolidation, and analytical processes, were documented to promote transparency and reproducibility. Artificial intelligence tools, where applicable, were used responsibly only to support language refinement, organization, and improvement of manuscript clarity; all AI-assisted outputs were critically reviewed and validated by the authors, who retained full responsibility for the accuracy, originality, interpretation, and integrity of the study. AI was not used to fabricate data, sources, results, or analyses, nor to replace the authors' scholarly judgment. The authors declare no financial, professional, institutional, or personal conflicts of interest that could have influenced the conduct, interpretation, or reporting of this study.

RESULTS AND DISCUSSIONS

This section presents and interprets the findings of the patent landscape analysis of fermented food innovations targeting gut health based on the final dataset of 189 simple patent families. Because individual patent families may contain multiple publications, filings, or jurisdictional records, some analyses presented below refer to patent documents rather than unique patent families. The findings are organized according to temporal patterns, patent-document characteristics, geographic distribution, technological classifications, innovation actors, citation influence, legal status, and technology gaps and white spaces. Collectively, these indicators provide an integrated view of the technological trajectory of fermented food innovations targeting gut health and serve as the empirical basis for the proposed Innovation Pathways Framework.

Patent Documents Over Time

The temporal distribution of patent documents related to fermented food innovations targeting gut health demonstrates a clear long-term expansion in inventive activity, although the trajectory is characterized by substantial year-to-year variation (Figure 2). Patent activity remained relatively limited from 1999 through the late 2000s, with annual document counts generally ranging from zero to approximately seven. This pattern suggests that, during this period, the technological intersection of fermented foods, microorganisms, and gut health was still developing as a relatively specialized innovation area. A more noticeable increase emerged between 2010 and 2015, followed by sustained growth beginning in 2016. Patent activity increased from approximately 15 documents in 2016 to around 18 documents in 2019, before accelerating to approximately 26 documents in 2020. The highest levels of activity were observed in the most recent years, particularly in 2023 and 2025, with approximately 37 and 38 documents, respectively.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 2. Patent Documents Over time on Fermented Foods for Gut Health

The overall trajectory indicates increasing technological and commercial attention to fermented foods and their potential applications in gastrointestinal and microbiome-related health. This expansion is consistent with the broader scientific development of research on fermented foods, microbial exposure, fermentation-derived metabolites, and interactions between food-associated microorganisms and the gastrointestinal environment. Contemporary research recognizes fermented foods as complex biological systems containing

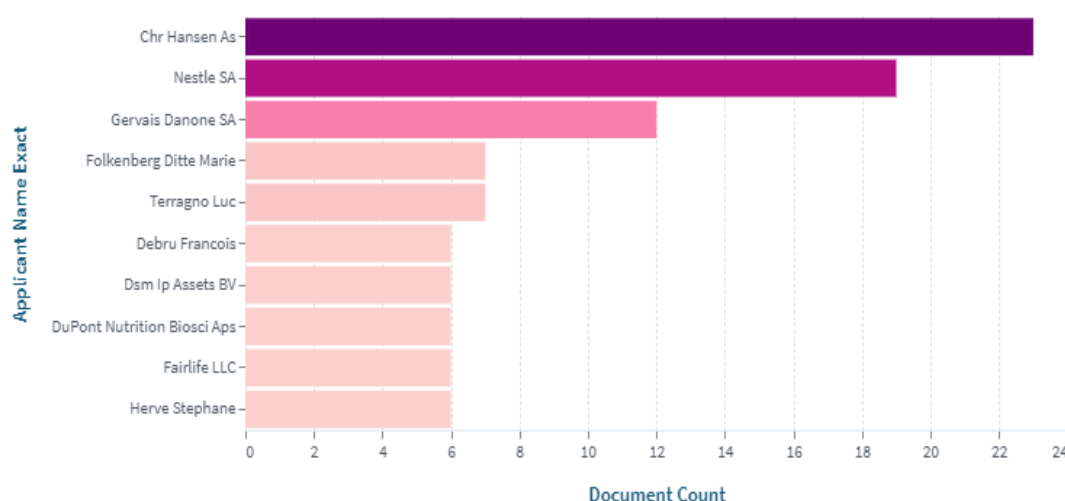
microorganisms, transformed food components, and fermentation-derived bioactive compounds that may influence gastrointestinal processes through multiple mechanisms (Marco et al., 2021; Mukherjee et al., 2024). The growing scientific interest in these mechanisms may have contributed to increasing efforts to translate research findings into proprietary food products, microbial formulations, fermentation processes, and other protectable technologies.

The fluctuations observed throughout the temporal distribution indicate that innovation in this field has not followed a uniform linear trajectory. Periods of rapid patent growth may reflect intensified research and development, increased commercial interest, or the emergence of new technological opportunities, whereas temporary declines may be associated with changes in filing strategies, innovation cycles, or delays between invention, filing, and publication. Patent counts should therefore be interpreted as indicators of inventive and patenting activity rather than direct measures of technological quality or commercial success. Patent data are widely used to examine technological development and inventive activity, but their interpretation requires consideration of institutional, legal, and strategic factors influencing patenting behavior (Hall et al., 2005; OECD, 2009).

The relatively low count for 2026 should also be interpreted cautiously because patent publications for the year may not yet be complete at the time of data retrieval. This observation illustrates a common limitation in temporal patent analysis, particularly when recent years are included. Overall, the temporal pattern suggests that fermented food innovations targeting gut health have progressed from relatively limited technological activity toward a more active and expanding innovation domain. Nevertheless, increasing patent activity does not necessarily indicate that all technological opportunities have been explored. When interpreted together with technological classifications, innovation actors, jurisdictions, and citation patterns, the temporal results provide an important basis for distinguishing highly concentrated technological pathways from comparatively underrepresented areas that may offer opportunities for future innovation.

Top Applicants

Figure 3 presents the leading patent applicants in fermented food innovations targeting gut health. The distribution reveals a moderately concentrated innovation landscape in which a relatively small number of organizations account for a substantial share of patenting activity. Chr. Hansen A/S emerged as the leading applicant, with approximately 23 patent documents, followed by Nestlé S.A. with approximately 19 documents and Gervais Danone S.A. with around 12 documents. A second group of applicants, including Folkenberg Ditte Marie and Terragno Luc., recorded approximately seven documents each, while the remaining leading applicants generally accounted for six or fewer documents.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 3. Top Patent Applicants on Fermented Foods for Gut Health

The prominence of major food, dairy, and bioscience organizations is consistent with the technological composition of the patent landscape, which is strongly associated with microbial cultures, fermented food matrices, probiotics, and nutrition-oriented applications. Established companies may possess substantial capabilities in food biotechnology, microbial culture development, clinical or nutritional research, product development, regulatory compliance, and intellectual property management. Consequently, repeated patenting activity by these organizations may reflect sustained strategic investment in technologies associated with fermented foods and gut health.

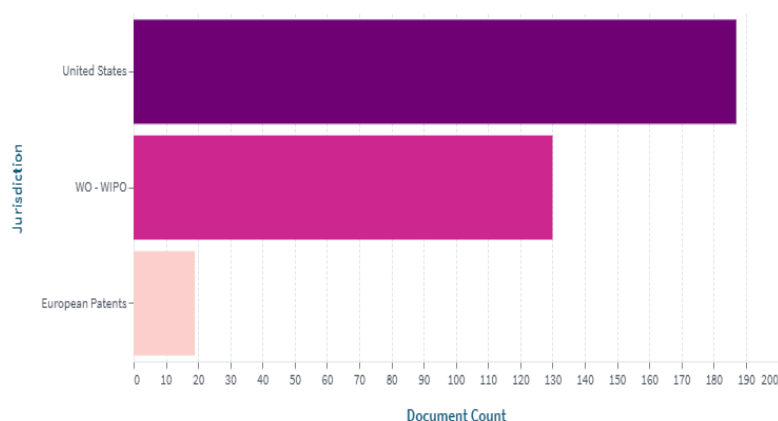
Patent applicant analysis provides useful information about the institutional structure of technological development because applicants often represent organizations that invest resources in the development and protection of inventions. However, patent applicant counts should not be interpreted solely as indicators of technological superiority because patent portfolios can also be influenced by corporate structure, filing strategies, acquisitions, and differences in intellectual property management practices (OECD, 2009; Squicciarini et al., 2013).

The difference between the leading applicants and the remainder of the distribution suggests some degree of concentration but does not indicate monopoly control of the technological field. The presence of multiple organizations and individual applicants suggests that the innovation landscape remains relatively diverse. This diversity may provide opportunities for universities, public research institutions, start-ups, and emerging food innovators to participate in less concentrated technological niches.

From an innovation perspective, the applicant distribution may therefore be interpreted in two complementary ways. First, the presence of leading corporate actors indicates that certain technological areas have already attracted substantial investment and intellectual property activity. Second, the absence of a single overwhelmingly dominant applicant suggests that opportunities remain for new entrants, particularly in areas involving alternative food matrices, novel microbial resources, localized fermentation systems, and differentiated gut-health functions. These patterns become particularly relevant when integrated with the CPC and IPCR analyses to identify technological areas that are highly populated and those that remain comparatively less developed.

Patent Documents by Jurisdiction

Figure 4 presents the distribution of patent documents across major patent jurisdictions. The United States recorded the largest number of patent documents, with approximately 187 records, followed by the World Intellectual Property Organization (WO–WIPO) international filing route with approximately 130 records and the European Patent Office (EP) with approximately 19 records. These counts should be interpreted as patent-document occurrences across jurisdictions rather than unique inventions because a single patent family may generate multiple filings or publications in different patent systems. Thus, the jurisdictional totals can exceed the number of simple patent families included in the study.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 4. Patent Documents on Fermented Food for Gut Health by Jurisdiction

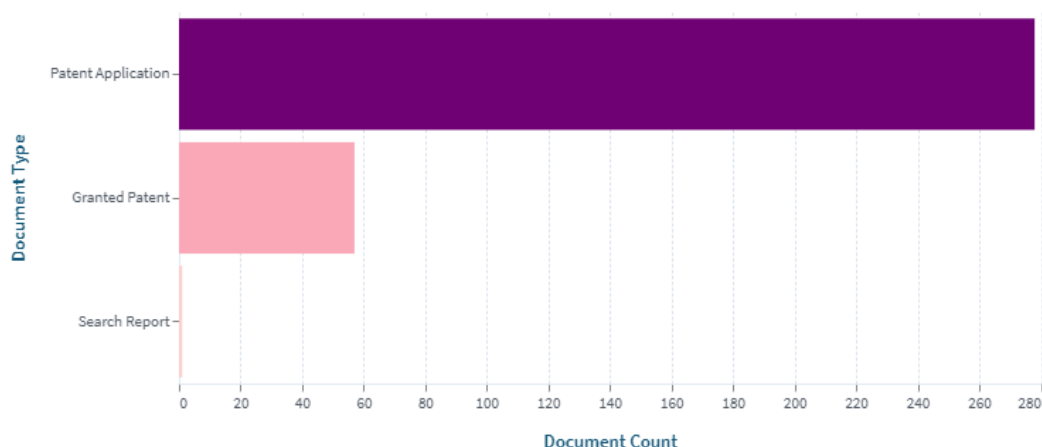
The strong representation of the United States suggests that it constitutes an important jurisdiction for intellectual property protection in fermented food technologies targeting gut health. The United States has a large food, biotechnology, and health-related consumer market and is an important destination for international patent protection. Patent filings in a particular jurisdiction may reflect market expectations, commercialization strategies, technological capacity, or the perceived importance of securing intellectual property rights in that market (OECD, 2009).

The substantial representation of WO–WIPO records should be interpreted differently from national or regional jurisdictions. The Patent Cooperation Treaty (PCT) provides an international filing mechanism that allows applicants to seek patent protection across multiple jurisdictions through a coordinated procedure; however, a PCT application does not itself constitute a patent enforceable in all participating countries (WIPO, n.d.). Consequently, the high number of WO–WIPO records indicate that many applicants consider the underlying technologies potentially relevant to international markets and may intend to pursue protection in multiple jurisdictions. The comparatively smaller representation of European Patent Office documents does not necessarily indicate limited technological activity in Europe. Patent filing patterns are influenced by differences in filing strategies, business priorities, costs, corporate structures, and the geographic markets targeted by applicants. Therefore, jurisdictional patent counts should be interpreted primarily as indicators of intellectual property protection strategies rather than direct measures of where inventions originated.

The geographic distribution nevertheless reveals a clear concentration of patent protection in major international markets. Jurisdictions with relatively limited representation may constitute potential geographic innovation spaces, particularly where countries possess rich agricultural biodiversity, indigenous fermented foods, and established fermentation traditions but have limited translation of these resources into internationally protected technologies. Such geographic underrepresentation should be investigated carefully because low patent activity may reflect institutional or financial barriers to patenting rather than the absence of scientific or technological potential.

Patent Documents by Type

The distribution of patent documents by document type demonstrates a strong predominance of published applications, followed by granted patents, while search reports represent only a minimal proportion of the dataset (Figure 5). Approximately 280 records were identified as published applications, compared with approximately 58 granted patents.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 5. Patent Documents on Fermented Food for Gut Health by Type

The predominance of published applications suggests substantial ongoing inventive activity within the technological field. Patent applications may represent technologies at different stages of examination and do not necessarily result in eventual patent grants. In contrast, granted patents have successfully completed the relevant examination procedures and have met the applicable legal requirements for patent protection. Consequently, the distinction between applications and grants provides information about the developmental and legal status of technological inventions (OECD, 2009; Squicciarini et al., 2013).

The observed pattern is consistent with the temporal analysis, which demonstrated increased patent activity during recent years. A growing number of applications may indicate that new inventions are entering the patent system, particularly in emerging areas involving microbial technologies, functional foods, fermentation processes, and gut-health-oriented products. However, the high number of applications should not automatically be interpreted as evidence that all inventions will reach commercialization or receive patent protection.

The smaller number of granted patents suggests that a substantial proportion of the technological landscape remains in the application or examination phase. This pattern is characteristic of a field experiencing continuing technological development, in which established inventions coexist with emerging technological concepts. The coexistence of granted patents and a larger number of applications indicate simultaneous consolidation and expansion.

From the perspective of innovation-gap identification, the document-type distribution may help distinguish relatively mature technological areas from areas undergoing more recent exploration. However, this distinction should be interpreted alongside patent age, legal status, classification, and substantive patent content. A high concentration of recent applications in a particular technological domain may indicate an emerging innovation frontier, whereas a concentration of older granted patents may suggest a more established technological pathway.

Top CPC Classification Codes

Figure 6 presents the leading Cooperative Patent Classification (CPC) codes identified in the patent landscape. The classification profile demonstrates that innovation in fermented foods targeting gut health is concentrated at the intersection of food technology, microbiology, microbial cultures, fermentation, and health-related food applications.

19 A23C11/106 Human Necessities Addition of, or treatment with, microorganisms A23C20/025 takes	26 A23C9/123 Human Necessities using only microorganisms of the genus lactobacteriaceae	50 A23C9/1234 Human Necessities characterised by using a Lactobacillus sp. other than	26 A23C9/1238 Human Necessities using specific L. bulgaricus or S. thermophilus microorganisms;	24 A23C9/1307 Human Necessities Milk products or derivatives; Fruit or vegetable juices; Sugars,
17 A23C9/1322 Human Necessities Inorganic compounds; Minerals, including organic	41 A23L2/382 Human Necessities fermented nut meats or seeds A23L25/40 ;	18 A23L2/84 Human Necessities using microorganisms or biological material, e.g.	83 A23L33/135 Human Necessities Bacteria or derivatives thereof, e.g. probiotics	29 A23L33/21 Human Necessities Addition of substantially indigestible substances, e.g.
67 A23V2002/00 Human Necessities Food compositions, function of food ingredients or	38 A61K35/747 Human Necessities Lactobacilli, e.g. L. acidophilus or L. brevis	58 C12N1/20 Chemistry metallurgy Bacteria Culture media therefor	39 C12N1/205 Chemistry metallurgy Bacterial isolates	20 C12R2001/225 Chemistry metallurgy Lactobacillus
>80.5				0

Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 6. Top Cooperative Patent Classification (CPC) Codes for Fermented Food Innovations Targeting Gut Health

The most frequently represented classification was A23L33/135, with approximately 83 documents, followed by A23V002/00, with approximately 67 documents. Other highly represented classifications included C12N1/20, A23C9/1234, and A23L2/382. Collectively, these classifications indicate substantial technological activity involving bacteria and bacterial derivatives, food compositions and ingredients, microbial culture technologies, fermented milk systems, and fermented plant-based or fruit-derived materials.

Patent classification systems provide a structured method for organizing patent documents according to their technological content. The CPC, developed and maintained through cooperation between major patent offices, provides detailed classifications that facilitate the identification of technological clusters and relationships within large patent datasets (EPO & USPTO, n.d.; WIPO, 2025). Consequently, the frequency of CPC codes provides a useful indication of the technological domains in which inventive activity is concentrated.

The high representation of classifications associated with bacteria, microbial cultures, and food compositions indicates that microorganisms constitute a central technological component of fermented food innovations targeting gut health. This finding is consistent with contemporary scientific literature emphasizing the importance of food-associated microorganisms and fermentation-derived compounds in the potential biological effects of fermented foods. Fermentation can modify food substrates and generate or enrich metabolites and bioactive components while introducing microorganisms or microbial components that may interact with the gastrointestinal environment (Marco et al., 2021; Mukherjee et al., 2024).

The prominence of dairy-related classifications further indicates that fermented milk products remain an important technological platform within the patent landscape. However, the presence of classifications involving fruits, nuts, seeds, and other food materials also suggests diversification beyond conventional dairy systems.

Importantly, concentration in microbial and dairy-related technological classifications may also indicate potential opportunities outside dominant pathways. Comparatively lower representation of alternative microbial species, mixed microbial communities, non-dairy food matrices, and metabolite-focused technologies suggests potential areas for future exploration. Such opportunities should not be interpreted as completely patent-free spaces but rather as comparatively less concentrated technological domains requiring more detailed patent and freedom-to-operate analysis.

Potential areas for future development include non-dairy fermented foods, underutilized agricultural substrates, novel microbial consortia, postbiotic-rich products, and fermentation strategies designed to generate specific metabolites or functional properties. These directions are supported by the growing recognition that fermented foods vary substantially in microbial composition and biochemical characteristics and that their effects cannot be generalized across all products (Marco et al., 2021; Mukherjee et al., 2024).

Top International Patent Classification-Reformed (IPCR) Classification Codes

The distribution of International Patent Classification-Reformed (IPCR) codes further demonstrates the convergence of food processing, microbiology, fermentation, and functional food technologies within the patent landscape (Figure 7). The most frequently represented classification was A23C9/123, with approximately 62 documents, followed by C12N1/20 with approximately 51 documents and A23C9/12 with approximately 42 documents. Other prominent classifications included A23L33/135, A23C9/13, and A23L2/38.

42 A23C9/12 Human Necessities Fermented milk preparations Treatment using microorganisms	62 A23C9/123 Human Necessities using only microorganisms of the genus lactobacteriaceae	33 A23C9/13 Human Necessities using additives	12 A23C9/133 Human Necessities Fruit or vegetables	14 A23L19/00 Human Necessities Products from fruits or vegetables Preparation or
27 A23L2/38 Human Necessities Other non-alcoholic beverages drinks from legumes	11 A23L2/84 Human Necessities using microorganisms or biological material, e.g.	22 A23L29/00 Human Necessities Foods or foodstuffs containing additives	18 A23L33/00 Human Necessities Modifying nutritive qualities of foods Dietetic products	37 A23L33/135 Human Necessities Bacteria or derivatives thereof, e.g. probiotics
11 A23L33/21 Human Necessities Addition of substantially indigestible substances, e.g.	12 A23L7/10 Human Necessities Cereal-derived products	25 A23L7/104 Human Necessities Fermentation of farinaceous cereal or cereal material Addition	21 A61K35/747 Human Necessities Lactobacilli, e.g. L. acidophilus or L. brevis	51 C12N1/20 Chemistry metallurgy Bacteria Culture media therefor
>59.5				0

Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use

Figure 7. Top International Patent Classification-Reformed (IPCR) Codes for Fermented Food Innovations Targeting Gut Health

The prominence of classifications associated with fermented milk preparations, bacterial cultures, and microorganisms suggests that dairy fermentation and bacteria-centered technological approaches constitute important foundations of innovation in this field. This pattern complements the CPC findings and reinforces the observation that microbial fermentation technologies remain central to patented innovations targeting gut health.

The IPC provides a hierarchical and internationally standardized system for classifying inventions according to technological fields. Its use facilitates the comparison and organization of patent information across countries and patent offices (WIPO, 2025). Accordingly, IPCR analysis can provide an additional perspective on the technological structure of the patent landscape and can complement the more detailed classification information provided by CPC codes.

The combined CPC and IPCR findings demonstrate both technological concentration and diversification. On one hand, bacterial cultures, Lactobacillaceae-related technologies, probiotics, and fermented dairy products occupy prominent positions within the landscape. On the other hand, the presence of classifications associated with beverages and alternative food substrates indicates that technological innovation is gradually extending beyond traditional dairy products.

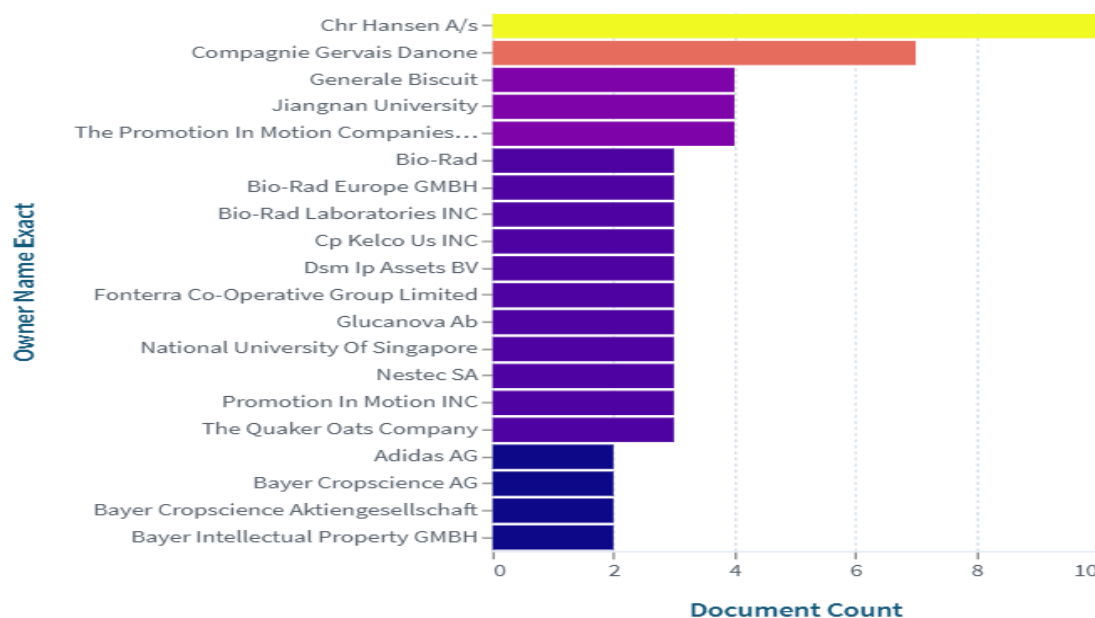
This distribution is consistent with scientific developments emphasizing the diversity of fermented foods and their associated microorganisms and metabolites. Fermented foods differ substantially according to substrate composition, fermentation conditions, microbial communities, and cultural production practices, resulting in considerable variation in their biological and technological characteristics (Marco et al., 2021; Mukherjee et al., 2024).

The concentration of patents in dairy- and bacteria-centered technological clusters therefore highlights possible opportunities in comparatively underrepresented areas, including plant-based fermented foods, indigenous fermentation substrates, mixed microbial consortia, non-conventional fermentation microorganisms, and targeted metabolite production. These areas require further examination because low

representation in classification data does not necessarily indicate the absence of relevant inventions. Nevertheless, comparative underrepresentation can provide a useful starting point for identifying potential technology gaps and innovation white spaces.

Top Patent Owners

Figure 8 presents the leading owners of patents related to fermented food innovations targeting gut health. Chr. Hansen A/S emerged as the leading owner, with approximately 10 patent documents, followed by Compagnie Gervais Danone with approximately seven documents. A second group including Generale Biscuit, Jiangnan University, The Promotion in Motion Companies, Bio-Rad, and other corporate and academic entities generally held between three and four documents.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 8. Top Patent Owners in Fermented Food Innovations Targeting Gut Health

The ownership distribution indicates that intellectual property in this technological field is shared among commercial enterprises, universities, research institutions, and biotechnology-oriented organizations. The presence of both corporate and academic owners suggests that innovation is generated through multiple institutional pathways.

Patent ownership provides information about the entities that control or have acquired rights to patented technologies. Ownership patterns may therefore provide insights into the organizational structure of innovation, commercialization strategies, technology transfer, and the relationship between knowledge-producing institutions and industry (Mowery et al., 2001; OECD, 2009).

The prominence of companies with established expertise in microbial cultures, food products, and nutrition-oriented technologies is consistent with the technological composition identified through the classification analyses. Corporate ownership may reflect the commercial relevance of microbial cultures and functional food technologies, whereas university and research institution ownership may indicate the continuing contribution of publicly funded or academic research to technological development.

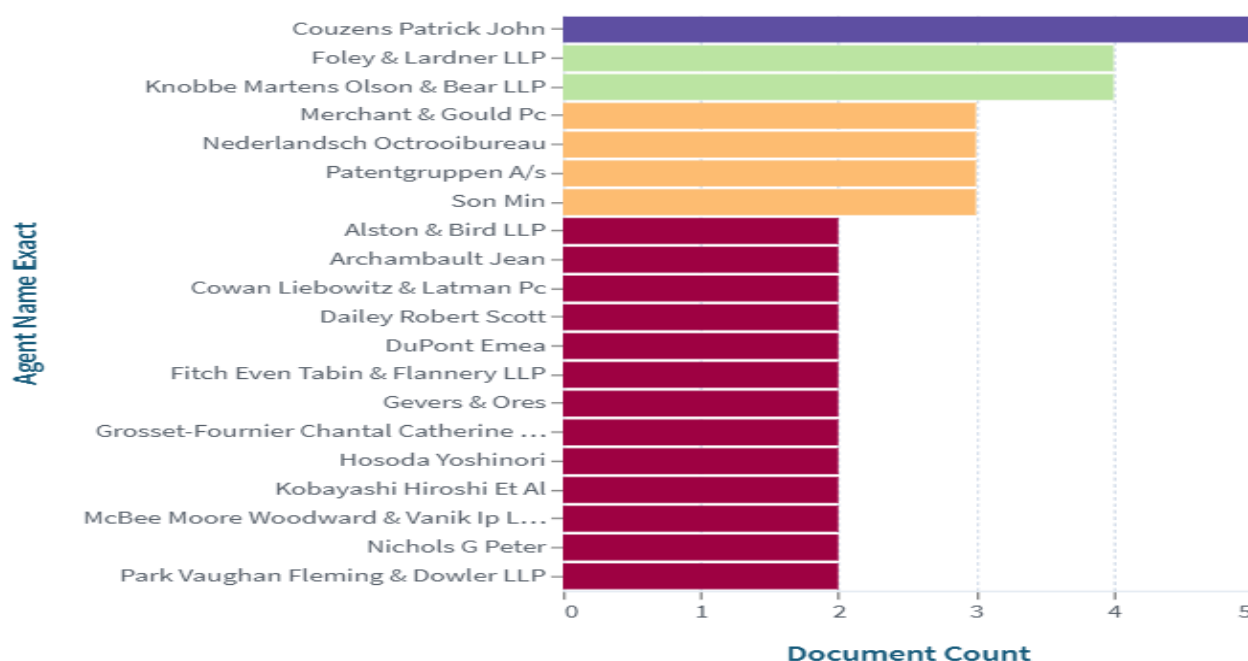
Despite the presence of leading owners, the ownership structure is not dominated by a single organization. The relatively dispersed distribution among the remaining owners suggests that opportunities may exist for collaboration, technology transfer, and new market entry. This is particularly relevant for emerging

innovators and research institutions that may develop technologies in less concentrated areas involving local fermentation resources, alternative food matrices, or specialized gut-health functions.

However, ownership analysis should be interpreted cautiously because ownership may change through acquisition, licensing, mergers, and reassignment. Patent ownership data therefore represent the ownership status reflected in the database at the time of retrieval rather than a permanent representation of institutional control.

Top Agents and Attorneys

Figure 9 presents the leading patent agents and attorneys associated with patent documents in fermented food innovations targeting gut health. The distribution is headed by Couzens Patrick John, who appeared in approximately five patent documents. This was followed by Foley & Lardner LLP and Knobbe Martens Olson & Bear LLP, each associated with approximately four documents. Merchant & Gould PC, Nederlandsch Octrooibureau, Patentgruppen A/S, and Soni Milán each appeared in approximately three documents, while several other patent representatives were associated with approximately two documents. The distribution is relatively dispersed, with no single patent agent or attorney accounting for a large proportion of the documents represented in the figure.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 9. Top Patent Agents and Attorneys in Fermented Food Innovations Targeting Gut Health

The relatively dispersed distribution of patent representatives suggests that intellectual property prosecution in fermented food innovations targeting gut health is supported by multiple professional networks rather than being concentrated around one dominant patent representative. Although Couzens Patrick John has the highest frequency in the figure, the difference between the leading representative and the next group is relatively small. The presence of several firms and individual representatives across the two- to four-document range indicates that patenting activity in this technological domain may involve different legal and intellectual property service providers. This pattern is consistent with a patent landscape in which applicants rely on diverse professional networks to prepare, prosecute, and manage patent applications.

The agent and attorney indicator contributes a different dimension to the patent landscape from other commonly examined indicators. Applicant and assignee analyses primarily identify organizations associated

with patent filing or ownership, whereas inventor analysis identifies individuals credited with developing the claimed inventions. Patent agents and attorneys, in contrast, provide information about the professional intermediaries involved in the formal intellectual property process. Their appearance in patent records may therefore reflect involvement in preparing applications, drafting and refining claims, responding to examination requirements, and managing patent prosecution. Consequently, this indicator is useful for examining the professional infrastructure supporting the conversion of technological developments into patent assets.

However, the frequency of an agent or attorney in patent documents should not be interpreted as evidence of technological superiority, scientific importance, patent quality, commercial success, or innovation impact. A higher document count may simply reflect repeated representation of a particular applicant, organizational relationship, jurisdictional filing strategy, or portfolio of related inventions. Similarly, the lower frequency of other representatives does not imply that the technologies they handled are less important or less innovative. The indicator therefore reflects patent-prosecution activity rather than the substantive technological value of the inventions.

The observed distribution may be associated with several characteristics of fermented food innovation. Technologies targeting gut health frequently involve interdisciplinary subject areas, including microbial fermentation, probiotic microorganisms, food compositions, functional ingredients, microbial strains, and processing technologies. Such inventions may require specialized intellectual property support because the scope of protection can depend on how biological materials, compositions, processes, and applications are technically and legally defined. In addition, applicants seeking protection across multiple countries may engage patent professionals with experience in particular jurisdictions or international filing procedures. Thus, the recurrence of particular representatives may reflect established professional relationships, specialization in biotechnology or food-related patents, geographical considerations, or continuing representation of organizations with active portfolios in the field.

The figure also complements the broader patent landscape by showing that the development of fermented food technologies is accompanied by an intellectual property support structure involving multiple legal and patent-service networks. When considered alongside applicant and ownership distributions, the agent and attorney data can help distinguish between the organizations developing or owning technologies and the professional networks facilitating their legal protection. When examined together with inventor and technological-classification data, the indicator may further help reveal whether recurring patent representatives are associated with particular technological areas, organizations, or clusters of inventive activity. This makes the figure particularly useful for understanding not only who develops and owns technologies, but also how those technologies are processed through the intellectual property system.

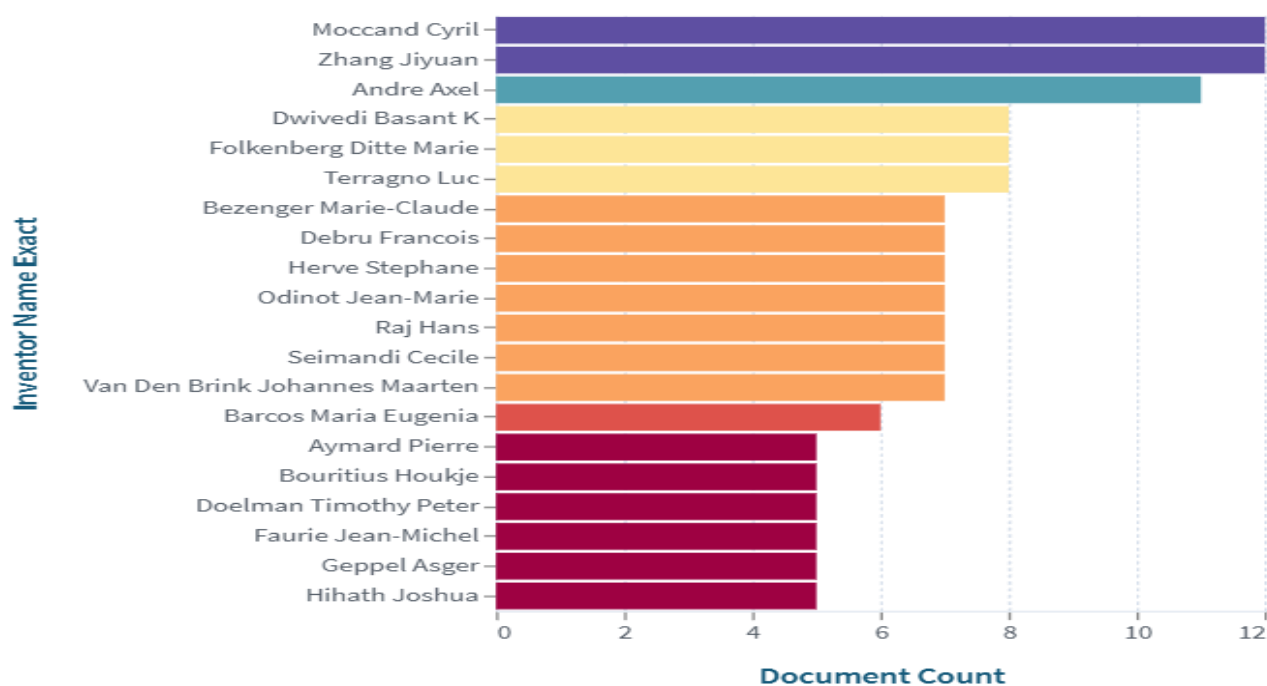
Interpretation of the figure should nevertheless consider several data-related limitations. The document counts are based on patent records retrieved and visualized through the Lens database and may be affected by patent-family structures, repeated filings, jurisdictional differences, and variations in how representatives are recorded. A single underlying invention may generate multiple patent documents across jurisdictions, potentially increasing the apparent frequency of a representative. In addition, differences in the recording or standardization of individual names and law-firm names may influence the distribution. Consequently, the values shown should be interpreted as document-level representation frequencies within the retrieved dataset, rather than as definitive counts of unique inventions or individual patent portfolios.

Figure 9 demonstrates that the patenting of fermented food innovations targeting gut health is supported by a diverse and relatively decentralized network of patent agents and attorneys. The absence of a highly dominant representative suggests that intellectual property activity in this field is distributed among multiple professional channels. While this indicator does not establish technological leadership, it provides an important complementary view of the institutional and professional infrastructure through which fermentation- and gut-health-related discoveries are translated into formal intellectual property protection. In the broader landscape, such diversity may be relevant to understanding international patenting strategies,

specialization, collaboration, and the mechanisms through which emerging fermented food technologies move from scientific and technological development toward potentially protectable innovations.

Top Inventors

Figure 10 presents the leading inventors contributing to patented innovations in fermented foods targeting gut health. Moccand Cyril and Zhang Jiyuan recorded the highest inventor frequency, with approximately 12 patent documents each, followed by André Axel with approximately 11 documents. A second tier of inventors, including Dwivedi Basant K., Folkenberg Ditte Marie, and Terragno Luc., appeared in approximately 8 documents each. Overall, the distribution shows a small group of highly recurrent inventors followed by a broader group with progressively lower document frequencies, indicating that inventive activity is relatively distributed but includes several individuals with sustained participation in the field.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 10. Top Inventors in Fermented Food Innovations Targeting Gut Health

The concentration of the highest document counts among Moccand Cyril, Zhang Jiyuan, and André Axel suggests that certain inventors have been repeatedly involved in patenting activity within fermented food technologies targeting gut health. However, the relatively gradual decline from approximately 12 documents among the top inventors to approximately 5 documents among the remaining inventors indicates that inventive participation is not restricted to only a few individuals. Instead, the figure reflects a tiered but relatively distributed inventor landscape, consisting of a small leading group followed by several contributors with substantial and recurring patent involvement.

This pattern may indicate the presence of established research and development teams or technological programs in which particular inventors have maintained sustained participation. Repeated appearance across patent documents may reflect continuing work on related fermentation technologies, microbial systems, functional food products, or gut-health applications. The relatively large number of inventors appearing with five to eight documents, however, suggests that technological development is supported by a wider pool of contributors rather than being entirely dependent on the most frequently appearing individuals.

Inventorship provides an important human-centered indicator of technological knowledge creation. Unlike applicant or assignee analysis, which identifies organizations associated with filing or ownership, inventor

analysis identifies the individuals formally credited with developing the inventions disclosed in patent applications. It therefore helps illuminate the people involved in the inventive process and can provide a basis for examining potential knowledge networks, recurring contributors, and collaborative research structures. This indicator differs from patent classification, which describes the technological domain of an invention, and from jurisdictional analysis, which identifies the geographic locations in which patent protection is sought.

The document frequency of an inventor should nevertheless not be interpreted as a direct measure of scientific productivity, technological superiority, innovation quality, commercial success, or research impact. A high inventor count may result from an individual's participation in several related applications, continuation or international filings, or a sustained role within an organization's research program. Likewise, an inventor with fewer patent-document appearances may have made an important contribution to an invention with substantial technological or commercial relevance. The figure therefore indicates frequency of patent-recorded inventive participation, rather than a ranking of individual technological achievement.

The observed pattern is plausible within the context of fermented food innovation because the development of gut-health-oriented technologies is inherently multidisciplinary and often collaborative. Fermented food inventions may combine microbial selection and characterization, fermentation processes, food formulation, probiotic or functional-ingredient development, nutritional applications, and methods for improving the health-related properties of food products. These activities can require complementary expertise across microbiology, food science, biotechnology, nutrition, and industrial product development. The recurrence of particular inventors may therefore reflect established expertise and continuing participation in technological platforms that require such interdisciplinary knowledge.

The distribution also provides an indication of potential specialization within the innovation ecosystem. The leading inventors may represent researchers or technical personnel who have participated repeatedly in the development of technologies within this patent domain. At the same time, the substantial group of inventors with approximately five to eight documents indicates that inventive capability is distributed among multiple contributors. This may be particularly relevant to the development of fermented food technologies because innovation in this field can occur through collaborations among universities, research institutions, biotechnology companies, food manufacturers, and other technology-oriented organizations.

When integrated with the broader patent landscape, inventor activity can help explain the relationship between individual knowledge contributors and institutional patenting capacity. For example, comparing the inventor distribution with applicant and ownership data can reveal whether highly recurring inventors are concentrated within particular organizations or distributed across several institutions. Linking inventor activity with technological classifications can further indicate whether particular individuals are repeatedly associated with specific technological areas, such as probiotic microorganisms, fermentation processes, functional food compositions, or microbial-derived products. Similarly, temporal analysis could determine whether these inventors represent long-standing contributors or more recent entrants into the field.

The figure should, however, be interpreted with attention to inventor-name disambiguation and patent-family structure. Patent databases may record the same individual under variations in spelling, initials, name order, or other identifying formats, while different individuals may share similar names. Such inconsistencies can affect the apparent frequency of individual inventors. In addition, document counts may include related patent-family members or filings in different jurisdictions, meaning that a higher number of documents does not necessarily correspond to the same number of distinct inventions. Therefore, the values in Figure 9 are best understood as document-level inventor frequencies within the retrieved Lens dataset, unless additional inventor disambiguation and patent-family consolidation have been performed.

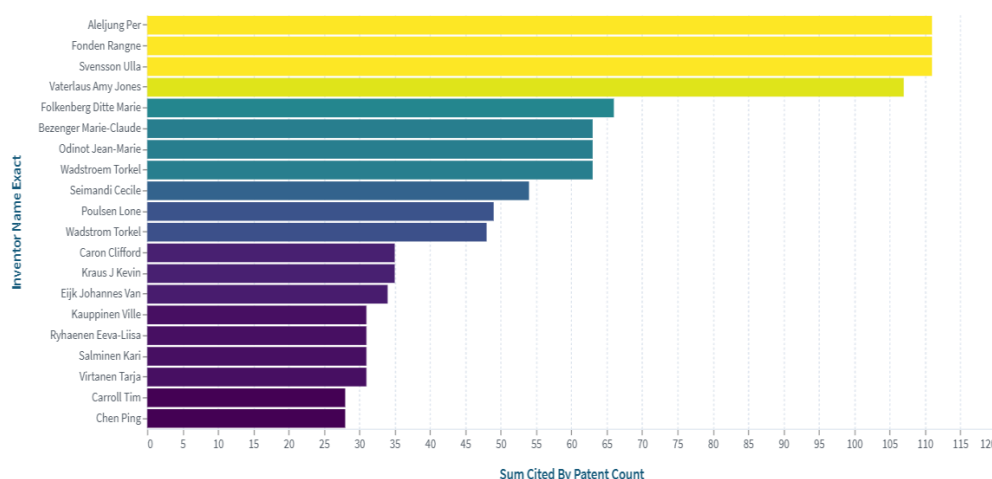
The inventor distribution complements the other components of the patent landscape by revealing the human knowledge base underlying the organizations and technologies represented in the dataset. Applicant and assignee analyses show where patenting and ownership are institutionally concentrated; inventor analysis identifies the individuals contributing to the inventive process; technological classifications indicate the

areas in which inventive activity occurs; and jurisdictional and temporal analyses provide geographic and historical context. Taken together, these indicators can provide a more comprehensive picture of how fermented food innovations targeting gut health are generated, organized, and translated into intellectual property.

Figure 10 indicates that inventive activity in fermented foods targeting gut health involves a recognizable group of recurring contributors alongside a broader base of active inventors. The presence of several inventors with substantial document frequencies suggests established expertise and continuing knowledge development, while the broader distribution indicates that technological development is not confined to a very small number of individuals. This pattern highlights the importance of human expertise, interdisciplinary collaboration, and sustained research and development activity in advancing fermented food technologies for gut-health applications. In the context of the broader patent landscape, identifying these recurring contributors can help reveal established technological capabilities and potential collaboration networks while also providing a basis for identifying less-developed areas where new researchers and institutions may contribute to future innovation.

Top Cited Inventors

Figure 11 presents the inventors associated with the most highly cited patents in the dataset. Alejung Per, Fonden Rangne, and Svensson Ulla were associated with the highest cumulative citation counts, each exceeding approximately 110 patent citations, followed by Vaterlaus Amy Jones with approximately 107 citations. Other inventors, including Folkenberg Ditte Marie, Bezenger Marie-Claude, Odinot Jean-Marie, and Wadstroem Torkel, were associated with substantial citation counts.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 11. Top Cited Inventors in Fermented Food Innovations Targeting Gut Health

The uneven distribution of patent citations suggests that technological influence is more concentrated than patent productivity. Although many individuals contribute to inventions in fermented foods targeting gut health, a smaller number of inventors are associated with patents that have received substantial attention from subsequent patent documents.

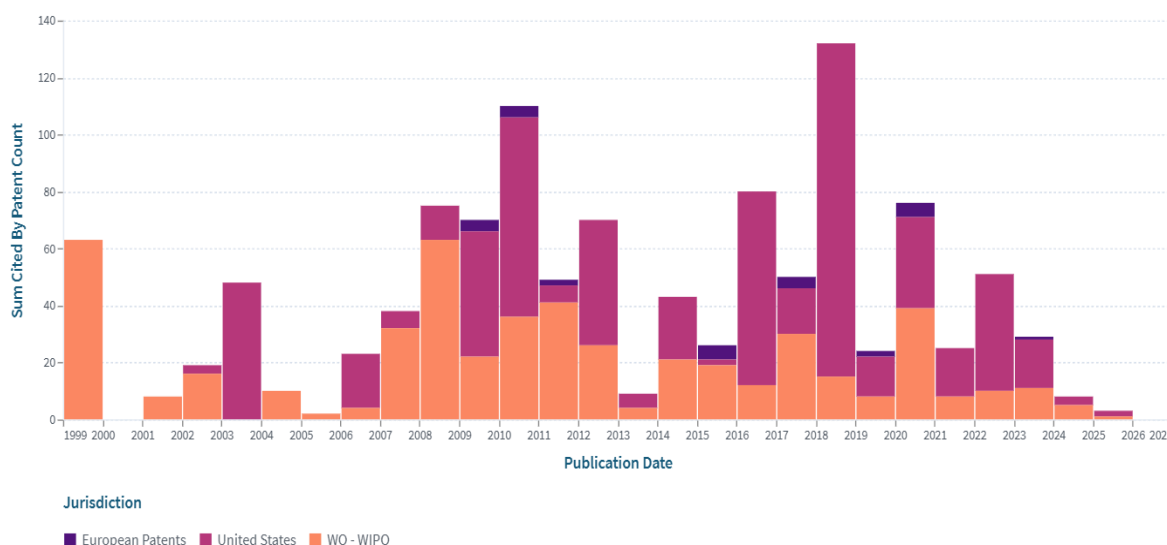
Patent citations have frequently been used as indicators of technological influence and knowledge flows because citations may indicate that subsequent inventions are related to or build upon earlier technological knowledge (Hall et al., 2005; Jaffe et al., 1993; Trajtenberg, 1990). However, citations should not be interpreted as definitive measures of patent quality or economic value. Citation behavior can also be influenced by patent age, technological field, examination practices, and differences in citation strategies.

The distinction between inventor productivity and citation influence is particularly important. An inventor with relatively few patents may nevertheless be associated with highly influential technological developments, whereas a highly prolific inventor may receive fewer citations. The present findings therefore suggest that technological influence in fermented food innovations targeting gut health is not determined solely by the number of inventions but also by the subsequent relevance of particular inventions to later technological development.

The citation analysis provides a useful basis for identifying influential technological trajectories. However, recent inventions should be interpreted cautiously because they have had less time to accumulate citations. Age-adjusted citation analysis could provide additional insights into the comparative influence of older and newer technological developments.

Cited Patent Influence by Jurisdiction

Figure 12 presents the temporal distribution of patent citations across the major jurisdictions represented in the dataset, including the United States, European Patent Office, and WO–WIPO records. Citation influence fluctuated considerably across publication years, with the most pronounced peak occurring around 2019, when United States patent documents accounted for approximately 130 citations.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 12. Top Cited Patent Classifications by Jurisdiction in Fermented Food Innovations Targeting Gut Health

Additional peaks were observed around 2010 and 2017, suggesting that technological influence has developed unevenly across time. The prominent contribution of United States patents is consistent with the overall jurisdictional distribution, which identified the United States as the most frequently represented patent jurisdiction in the dataset.

Patent citation relationships are commonly used to investigate technological knowledge flows and connections between earlier and subsequent inventions (Hall et al., 2005; Jaffe et al., 1993). A highly cited patent may have influenced subsequent technological developments or may occupy an important position within a technological trajectory. Nevertheless, citation counts are affected by the age of the patent, field-specific citation behavior, and the duration of the citation window.

The strong citation contribution of United States patent documents suggests that inventions protected or published within the United States patent system have played an important role in subsequent technological development within the dataset. However, this pattern should not be interpreted as evidence that innovation

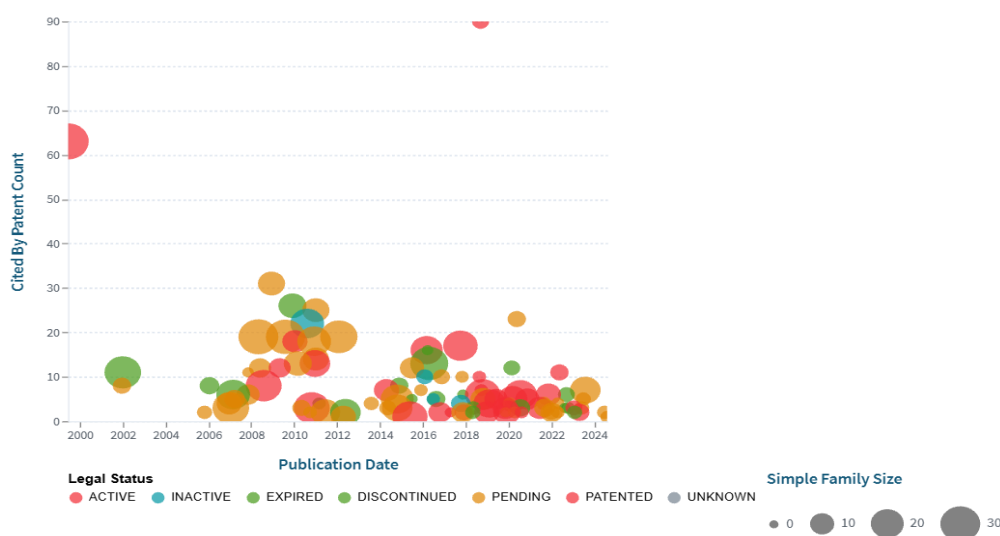
itself originates exclusively in the United States because patent filings may be made in jurisdictions different from the country in which research and development occurred.

European and WO–WIPO records also contribute to the citation landscape, demonstrating that technological knowledge is distributed across international patent systems. The combined results therefore indicate that the development of fermented food technologies targeting gut health involves transnational knowledge flows and intellectual property strategies.

When integrated with CPC and IPCR analyses, citation patterns can help identify technological clusters that have generated substantial downstream influence. Conversely, comparatively low citation activity may indicate either limited technological diffusion or simply the recency of inventions. Therefore, low citation counts should not automatically be equated with low technological importance.

Top Cited Patents Classified based on Legal Status

Figure 13 illustrates the relationship among patent citation counts, publication timing, legal status, and simple patent family size. The distribution demonstrates substantial inequality in technological citation influence. One early-period patent received approximately 64 citations, substantially exceeding most patents in the dataset. Additional influential patents were observed during the late 2000s and early 2010s, including one patent with approximately 31 citations and several patents receiving approximately 15–26 citations.



Note. Data visualization generated using the Lens patent database. The figure is reproduced from the Lens platform and is freely accessible for research and academic use.

Figure 13. Top Cited Patents by Legal Status in Fermented Food Innovations Targeting Gut Health

Most patents published during more recent years received fewer than 10 citations. However, this pattern should be interpreted with caution because patent citations accumulate over time. Older patents generally have had a longer period during which subsequent inventions can cite them, whereas recently published patents have had limited opportunity to accumulate citations (Hall et al., 2005; Trajtenberg, 1990).

The incorporation of legal status provides an additional dimension for interpreting technological influence. Legal status can indicate whether a patent or application remains active, has expired, has lapsed, or is otherwise no longer in force. This information is important when assessing the potential accessibility and strategic relevance of technological knowledge.

Highly cited patents that remain legally active may represent influential technological areas in which commercialization and freedom-to-operate considerations require careful analysis. Conversely, expired, lapsed, or discontinued patents may contain technological knowledge that can potentially be studied,

improved, adapted, or recombined, subject to verification of legal status and appropriate freedom-to-operate assessment. Importantly, the expiration or inactivity of a particular patent does not automatically mean that the underlying technology is free from other patents, continuation applications, related patent families, or other intellectual property restrictions.

The integration of citation impact, legal status, publication timing, and patent family information therefore provides a more nuanced basis for technology intelligence. It enables the identification of historically influential inventions, potentially active technological barriers, and knowledge areas that may warrant further investigation for technological adaptation or differentiation.

Patent Gaps and Innovation White Spaces

The integrated patent landscape findings indicate that fermented food innovations targeting gut health are progressing toward an increasingly active technological domain. The temporal analysis demonstrated sustained growth in patent activity, particularly from the mid-2010s onward, while the predominance of published applications suggests continuing technological development. However, increasing patent activity does not necessarily imply comprehensive exploration of all scientific and technological possibilities.

Instead, the combined evidence indicates that innovation is concentrated around particular technological pathways. The CPC and IPCR analyses show strong representation of bacterial cultures, probiotics, Lactobacillaceae-related technologies, fermented dairy products, and conventional functional food applications. This technological concentration is consistent with the broader scientific development of fermented food research, in which microorganisms and fermentation-derived compounds have received considerable attention as potential contributors to gastrointestinal health (Marco et al., 2021; Mukherjee et al., 2024).

The concentration of patent activity provides an analytical basis for identifying comparatively underrepresented technological domains. These areas should be interpreted as potential innovation white spaces rather than completely unexplored or patent-free fields. A technology may be considered relatively underrepresented because it has fewer patents, fewer applicants, weaker integration with adjacent technologies, or limited translation into commercially oriented inventions.

One important potential white space involves alternative fermented food matrices. The strong representation of dairy-related technologies suggests that fermented milk systems remain an important technological platform. Comparatively lower representation of plant-based, indigenous, and region-specific substrates indicates opportunities for further innovation involving cereals, legumes, fruits, vegetables, root crops, and other locally available agricultural resources. Such opportunities are scientifically relevant because the composition of fermented foods varies according to the substrate, fermentation environment, microbial community, and production practices, resulting in substantial diversity in microbial and metabolic characteristics (Marco et al., 2021; Mukherjee et al., 2024).

A second potential gap concerns microbial diversity. The patent landscape is strongly associated with bacterial and Lactobacillaceae-related technological pathways. Although these microorganisms have substantial scientific and commercial relevance, the concentration of innovation suggests opportunities to investigate alternative microorganisms, mixed microbial communities, and geographically localized fermentation cultures. Traditional fermented foods may contain diverse microbial ecosystems that remain insufficiently characterized or translated into modern food technologies. Systematic investigation of these microbial resources could support the identification of novel strains, microbial consortia, fermentation metabolites, and technological applications.

A third potential innovation area involves moving beyond generalized probiotic-centered approaches toward more differentiated fermentation-based functions. Fermented foods are increasingly recognized as complex systems in which microorganisms, transformed food components, and fermentation-derived metabolites may influence gastrointestinal processes through multiple mechanisms (Mukherjee et al., 2024). This creates

opportunities for technologies involving postbiotic components, microbial metabolites, exopolysaccharides, bioactive peptides, and other fermentation-derived compounds.

Potential innovation pathways may also include synbiotic food systems, precision fermentation approaches, and fermented foods designed around specific biological functions. However, technological development in these areas should be supported by appropriate mechanistic, safety, and human evidence because not all fermented foods or fermentation-associated microorganisms produce the same physiological effects (Marco et al., 2021; Mukherjee et al., 2024).

The applicant and ownership distributions reveal additional structural opportunities. Although Chr. Hansen A/S, Nestlé S.A., Gervais Danone S.A., and other major organizations occupy prominent positions within the landscape, the field is not dominated by a single applicant or owner. This relatively dispersed structure suggests opportunities for universities, public research institutions, start-ups, and regional innovators to enter less concentrated technological niches. Potential opportunities may be particularly relevant to innovators capable of combining local food resources with modern food biotechnology. Innovation need not arise exclusively from entirely new microorganisms or fermentation processes. Novelty may also emerge through the development of new combinations involving food matrices, microbial strains, fermentation conditions, functional mechanisms, product formats, and technological applications.

Geographic analysis reveals a further potential innovation gap. Patent activity is strongly concentrated in the United States and international WO–WIPO filings, whereas many jurisdictions with diverse fermented food traditions appear less represented. Low patent representation does not necessarily imply limited scientific or technological resources. Instead, it may reflect barriers associated with research funding, intellectual property infrastructure, technology transfer capacity, commercialization, and access to international patent systems.

Countries with substantial agricultural biodiversity and traditional fermentation practices may therefore represent important sources of future innovation. The Philippines, for example, possesses diverse agricultural resources and traditional food systems that may offer opportunities for developing differentiated fermented food technologies. However, the identification of such opportunities requires systematic microbiological characterization, functional validation, safety assessment, product development, market evaluation, and intellectual property analysis. Citation and legal-status analyses provide an additional perspective on innovation opportunities. Technological influence is concentrated among a relatively small number of highly cited patents and inventors, suggesting the existence of established technological trajectories. These highly cited areas may represent important foundations for future technological development but may also involve substantial intellectual property congestion.

Conversely, less-cited or comparatively underrepresented technological areas may provide opportunities for strategic differentiation. However, citation counts should not be used independently to identify white spaces because recently published patents have had less time to accumulate citations. Similarly, inactive or expired patents should not automatically be considered freely available technologies. Any attempt to adapt or commercialize technologies described in such patents should involve updated legal-status verification and comprehensive freedom-to-operate analysis.

Based on the integrated findings, the principal technology gaps and potential innovation white spaces can be organized into ten interconnected areas:

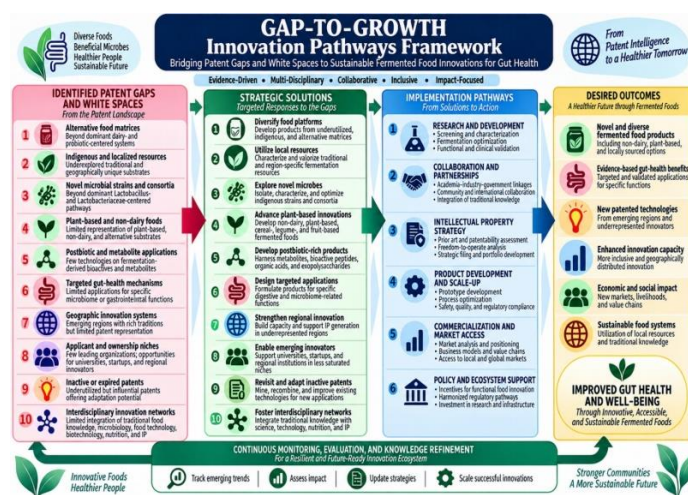
1. Alternative fermented food matrices beyond dominant dairy-based systems;
2. Indigenous and geographically localized fermentation resources that remain insufficiently translated into patented technologies;
3. Novel microbial strains and microbial consortia beyond highly represented conventional bacterial pathways;

4. Plant-based and non-dairy fermented foods utilizing diverse agricultural substrates;
5. Postbiotic and metabolite-oriented applications derived from fermentation processes;
6. Targeted gut-health functions supported by specific mechanisms rather than generalized health claims;
7. Emerging geographic innovation systems with limited international patent representation;
8. Less concentrated applicant and ownership niches that may provide opportunities for universities, start-ups, and regional innovators;
9. Strategic learning from historically influential technologies, particularly where legal and freedom-to-operate analyses identify opportunities for legitimate adaptation or differentiation; and
10. Interdisciplinary innovation networks integrating traditional food knowledge, microbiology, food technology, biotechnology, nutrition, commercialization, and intellectual property management.

These white spaces should not be interpreted as areas entirely devoid of patents or technological activity. Rather, they represent comparatively less concentrated, less mature, insufficiently integrated, or strategically underexplored areas relative to dominant technological clusters. Innovation opportunities may therefore emerge through novel recombination, localization, functional differentiation, and technological integration rather than through entirely unexplored scientific discoveries. Collectively, these findings provide the analytical bridge between descriptive patent mapping and the development of the proposed Innovation Pathways Framework. The framework is designed to translate patent intelligence into strategic directions for scientific research, technological development, intellectual property generation, product innovation, and commercialization.

The Gap-to-Growth Innovation Pathways Framework

The GAP-TO-GROWTH Innovation Pathways Framework was developed from the integrated findings of the patent landscape analysis to provide a structured pathway for translating identified technological gaps and innovation white spaces into future fermented food innovations targeting gut health (Figure 14).



Note. The GAP-TO-GROWTH Innovation Pathways Framework was developed by the researchers based on the findings of the patent landscape analysis, with the visual design and refinement of the framework aided by generative artificial intelligence (AI).

Figure 14. The GAP-TO-GROWTH Innovation Pathways Framework: Bridging Patent Gaps and White Spaces to Sustainable Fermented Food Innovations for Gut Health

The framework begins with Gap Identification, which is based on the integrated analysis of temporal trends, technological classifications, applicant and ownership structures, geographic distribution, citation influence, and legal status. The ten identified opportunity areas demonstrate that increasing patent activity does not necessarily equate to comprehensive technological exploration. Instead, substantial opportunities remain for diversification across food matrices, microbial resources, fermentation processes, metabolites, functional mechanisms, geographic contexts, and innovation networks.

The second component, Strategic Solutions, translates these identified gaps into potential research and innovation responses. These responses include the diversification of food platforms using underutilized and plant-based matrices; characterization and responsible utilization of localized fermentation resources; exploration of novel microbial strains and consortia; development of postbiotic-rich products and fermentation-derived metabolites; and the design of technologies addressing specific and scientifically substantiated gastrointestinal functions.

This approach recognizes that the potential functionality of fermented foods is influenced by interactions among the food matrix, microorganisms, fermentation conditions, metabolites, and the host gastrointestinal environment (Marco et al., 2021; Mukherjee et al., 2024). Consequently, the development of differentiated fermented food technologies requires interdisciplinary integration across food science, microbiology, biotechnology, nutrition, and microbiome research.

The strategic solutions are subsequently operationalized through six interconnected pathways:

Research and Development

Research and development provide the scientific foundation for innovation through microbial screening, characterization of fermentation ecosystems, process optimization, metabolite analysis, functional testing, and safety assessment. Scientific validation is essential because potential gut-health benefits cannot be generalized across fermented foods and must be supported by appropriate evidence (Marco et al., 2021; Mukherjee et al., 2024).

Collaboration and Partnerships

Collaboration connects universities, research institutions, food industries, biotechnology organizations, government agencies, farmers, and communities. Such partnerships can facilitate the exchange of knowledge and resources and support the translation of local food resources into scientifically validated technologies.

Intellectual Property Development

The intellectual property pathway includes prior-art searching, patentability assessment, strategic patent drafting, portfolio development, legal-status monitoring, and freedom-to-operate analysis. Patent intelligence can help innovators understand existing technological boundaries and identify opportunities for differentiation. However, patent landscape findings should be supplemented by professional legal analysis before commercialization decisions are made.

Product Development and Scale-Up

Promising technologies must be translated into products that are safe, stable, scalable, and acceptable to consumers. Product development should consider microbial viability or stability where relevant, sensory characteristics, shelf life, manufacturing feasibility, regulatory requirements, and consistency of functional properties.

Commercialization

Commercialization pathways involve market assessment, business development, consumer research, regulatory planning, and the establishment of appropriate production and distribution systems. Technological novelty alone is insufficient for successful innovation; products must also demonstrate feasibility and relevance to market and societal needs.

Policy and Innovation Ecosystem Support

The final pathway emphasizes the importance of supportive policies, research infrastructure, technology transfer mechanisms, investment, capacity building, and innovation incentives. Innovation emerges not only from scientific discovery but also from interactions among knowledge institutions, industry, government, and broader societal actors (Carayannis & Campbell, 2009; Etzkowitz & Leydesdorff, 2000).

The framework ultimately progresses toward outcomes that extend beyond patent generation. These include diversified fermented food products, scientifically substantiated and targeted applications, new technological platforms, stronger intellectual property portfolios, increased innovation capacity, economic opportunities, and more sustainable food systems.

The framework is intentionally iterative rather than linear. The continuous monitoring, evaluation, and knowledge-refinement component enables new scientific findings, market developments, technological advances, and patent activity to feed back into subsequent cycles of gap identification. This iterative process recognizes that technology landscapes evolve continuously and that innovation priorities should be periodically reassessed.

Overall, the GAP-TO-GROWTH Innovation Pathways Framework demonstrates how patent intelligence can move beyond descriptive mapping to support strategic decision-making. By systematically connecting technological concentrations and underrepresented areas with research, collaboration, intellectual property, product development, commercialization, and ecosystem support, the framework provides a forward-looking mechanism for guiding the development of novel, differentiated, and potentially sustainable fermented food innovations targeting gut health.

CONCLUSION

This study mapped the global patent landscape of fermented food innovations targeting gut health and revealed a rapidly expanding yet unevenly distributed technological field. Although patenting activity has increased substantially, innovation remains concentrated within dominant technological pathways, particularly dairy-based products, probiotic-oriented applications, and technologies involving *Lactobacillus* and related bacterial groups, as well as within major patent jurisdictions and established innovation actors. These patterns indicate that significant technological activity coexists with opportunities for diversification and further innovation.

Through the integration of multiple patent landscape dimensions—including temporal trends, geographic distribution, document characteristics, technological classifications, applicants and patent owners, inventorship, citation patterns, and legal status—the study identified several interconnected technology gaps and potential innovation white spaces. These include alternative food matrices, indigenous and geographically localized fermentation resources, novel microbial strains and microbial consortia, plant-based and non-dairy fermented products, postbiotic and metabolite-oriented applications, targeted gut-health functions, emerging geographic innovation systems, less concentrated applicant and ownership niches, opportunities for learning from historically influential patents subject to appropriate legal and freedom-to-operate assessment, and interdisciplinary innovation networks. These areas should be interpreted as comparatively underrepresented or strategically underexplored domains rather than entirely patent-free spaces.

A principal contribution of this study is the development of the GAP-TO-GROWTH Innovation Pathways Framework, which extends the application of patent landscape analysis beyond descriptive mapping. By systematically linking identified technological gaps and innovation white spaces with strategic solutions, implementation pathways, and potential innovation outcomes, the framework translates patent intelligence into a forward-looking mechanism for research, technology development, intellectual property generation, product innovation, and commercialization. The framework may assist researchers, universities, food industries, entrepreneurs, policymakers, and other innovation stakeholders in identifying differentiated and potentially viable pathways for advancing fermented food technologies targeting gut health.

The findings also highlight opportunities for geographically diverse and resource-rich regions to participate more actively in the development of fermented food technologies. In particular, countries with indigenous food resources, traditional fermentation practices, and substantial agricultural biodiversity may benefit from integrating local knowledge and biological resources with contemporary advances in food biotechnology, microbiology, product development, and intellectual property management. Such integration may support agricultural value addition, technology transfer, entrepreneurship, and the development of more inclusive innovation ecosystems.

The findings should, however, be interpreted in light of several limitations. Patent landscape results are influenced by the coverage, indexing practices, metadata quality, classification accuracy, and temporal completeness of the patent database used. In particular, recently published applications may remain under examination and have had insufficient time to accumulate patent citations. Patent ownership and legal status may also change over time, while patent classifications and metadata may contain inconsistencies that require verification. Furthermore, patent frequency or citation counts should not be interpreted as direct measures of technological quality, health efficacy, commercial success, or societal impact.

Despite these limitations, this study demonstrates that patent intelligence can serve not only as a tool for documenting existing technological activity but also as a strategic instrument for identifying technological concentrations, comparatively underexplored opportunities, and potential pathways for future innovation. The findings provide a foundation for future studies combining patent intelligence with scientific literature, market analysis, microbiological characterization, clinical or functional validation, and freedom-to-operate assessment. Ultimately, advancing fermented food innovations targeting gut health will require the responsible integration of scientific evidence, technological creativity, sustainable resource utilization, and strategic intellectual property development. Through this approach, patent intelligence can help support the development of differentiated, scientifically grounded, accessible, and sustainable fermented food innovations with potential relevance to gut health and broader food-system innovation.

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