2024 STATE OF THE INDUSTRY:

Fermentation

for meat, seafood, eggs, dairy, and ingredients

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Editor's note

Fermentation offers a powerful, here-and-now way to diversify the food supply.

In 2024, new fermentation-enabled products from whole-cut steaks to egg proteins hit supermarket shelves, helping to meet growing demand for foods loved around the world, made in vastly more efficient ways.

Growing enthusiasm and support for fermentation are evident in the uptick of public and private investments in the space. While biomass, precision, and traditional fermentation all exist in different stages of development (and utilize different production methods), fermentation as a whole showed resilience in an otherwise subdued funding environment in 2024. While greater support from governments and industry is needed to help fermentation-enabled protein production sustainably scale up, bring down costs, and create delicious, in-demand foods, the field is gaining momentum thanks to a growing global network of innovators who are just starting to scratch the surface of what's possible.

The early chapters of fermentation's story are defined by innovation, versatility, and promise.

Another notable page in that story was written in 2024, with market expansion, new and expanded partnerships, especially in dairy product and seafood product development, and the launch of new research centers and innovation hubs around the world. Meat and dairy products made from mycoprotein and mycelium expanded their reach, and product debuts included ice cream, milk, and yogurt made with whey from precision fermentation. The scientific ecosystem expanded with new pilot facilities, university-based research centers, and infrastructure investments from governments. Regulatory approvals marked steps forward around the globe, from Canada to New Zealand and beyond.

Like many transformative innovations in their early days, fermentation-enabled products face a set of difficult–if predictable–challenges, including early-stage funding constraints and technical and cost hurdles. Yes, these challenges are big. But in 2024, several bright spots emerged. Fermentation innovation progressed in research facilities and test kitchens, in food biomanufacturing centers and innovation hubs, and on college campuses and in classrooms.

If the world is to satisfy the growing demand for meat in vastly more sustainable ways, however, we'll need far more progress and at a quicker pace. In 2024, governments took meaningful steps in that direction. In the United States, promising public investments were made in food biomanufacturing, with much of that investment channeled toward fermentation innovation. Around the world, multiple countries increased their investments in alternative proteins as part of their broader bioeconomy plans and food security goals.

At GFI, we see a path forward that will help feed more people in ways that use fewer resources while bolstering food security and economies. Our annual State of the Industry report series equips food system stakeholders with an in-depth understanding of the alternative protein sector, including its biggest challenges and its major opportunities. This report, *Fermentation for meat, seafood, eggs, dairy, and ingredients*, details the major innovations and developments that moved the field of fermentation forward in 2024.

We remain grateful and inspired by all those around the world who are advancing alternative proteins, and as such, helping to write this next extraordinarily important chapter of food and agriculture.

Executive summary

The year 2024 included milestones across science, industry, and policy: the scientific ecosystem grew with new research centers and pilot facilities, mycoprotein continued to receive extensive R&D and commercialization interest, and significant regulatory approval milestones were seen in Canada and New Zealand.

The fermentation sector also faced challenges. Fermentation companies need access to more resources to expand product variety, increase scale, and implement process improvements. Looking ahead, fermentation companies must continue to pursue creative and multipronged funding strategies to access the capital needed for the industry to achieve scale.

This year, 165 companies focused primarily on fermentation. Another at least 210 diversified companies have joined the industry (through investments, partnerships, etc.), working along with a growing number of scientists to innovate and optimize fermentation-enabled foods so consumers can enjoy the foods they love made with a lighter footprint. In a challenging funding environment, the fermentation industry demonstrated resilience and raised $651 million in total private funding in 2024, all of which was raised by privately held companies, and according to GFI's estimates, another $510 million in public investments from governments. This represents an increase in funding totals year-over-year, with investors drawn to the sector often citing product functionality and high consumer favorability.

These are among the notable advancements in 2024:

Commercial landscape

- **New openings:** At least 16 fermentation facilities opened or were announced in 2024. Most of the activity occurred in the biomass and precision fermentation sectors, although at least one traditional fermentation facility opened and one was announced. At least five of those facilities were innovation hubs or research and development centers, which can help companies de-risk processes, demonstrate commercial viability, and reduce scale-up costs.
- **Involvement by diversified companies:** New activity in the fermentation sector from diversified companies accelerated in 2024. Diversified companies established partnerships, invested in companies and facilities, and debuted new fermentation-enabled products.
- **New partnerships**: At least 21 partnerships were formed in the fermentation sector in 2024, with especially robust activity in dairy product development and commercialization, seafood product development, and process optimization. Dairy end-product manufacturers, in particular, are recognizing fermentation's unique ability to efficiently produce functional ingredients, as several large conventional dairy companies partnered with fermentation companies in 2024.

Investments

- **Significant deals:** The four largest fermentation deals in 2024 were **Meati**'s $100 million Series C, **Perfect Day**'s $90 million Series E, **Formo**'s $61 million Series B, and **Infinite Roots**' $58 million Series B.
- **The long-view context:** Of the top four fermentation deals in 2024, only **Meati**'s ranks among the all-time top 10 largest investments in the fermentation sector. The investment environment of the past two years has been fundamentally different from the low-interest-rate period of 2019 to 2022, when the other nine largest fermentation rounds were raised.
- **Total raised**: Since the first disclosed investment in a fermentation company in 2013, privately held companies in the fermentation sector have raised $4.8 billion, while publicly traded companies have secured $39 million.

Science and technology

- **Scientific ecosystem gains healthy momentum**: Three new Centers of Excellence in Alternative Protein, funded by the Bezos Earth Fund, were founded at Imperial College London, the National University of Singapore, and North Carolina State University. Meanwhile, NAPIC and SUSFERM launched fermentation-focused research centers.
- **New pilot capabilities**: From Australia's FaBA to the iFAB in the U.S., new facilities were planned, while **MISTA** commissioned a high- and low-moisture extruder for piloting end products.
- **Precision fermentation advances in titer: EVERY Company** reported ovalbumin titers from 17-30 g/L in *K. phaffii,* and **Onego Bio** reported 120 g/L in *Trichoderma reesei*, representing significant strides over previously published titers in *S. cerevisiae*, *K. phaffii*, and *T. reesei*.

Government and regulation

- **Canada**: Canada approved fermentation-derived animal-free milk for the first time in January 2024, when Health Canada issued a "Letter of No Objection" indicating that it does not have food safety concerns about the use and sale of **Remilk**'s animal-free milk protein.
- **India**: In August 2024, the Indian Union Cabinet approved the BioE3 policy (Biotechnology for Economy, Environment, and Employment Policy for Fostering High-Performance Biomanufacturing) with smart protein (alternative proteins, including fermentation-derived proteins) as one of six key thematic sectors.
- **New Zealand**: In May 2024, New Zealand's **Daisy Lab**, a precision fermentation biotech company, received approval from the New Zealand Environmental Protection Authority (EPA) for their application to expand their dairy protein production platform to 5,000 liters. This regulatory approval will enable the construction of a pilot facility, marking a significant step forward in scaling and marketing this technology in New Zealand, the largest global dairy exporter.
- **United States**: In 2024, the United States government funded nearly 25 research projects or business grants advancing fermentation technology for defense, economic development, agricultural benefits, or nutrition enhancement, including a $51 million investment in precision fermentation capacity in Illinois.

Unless otherwise cited, all of the investment information presented in this "Executive Summary" is from GFI's analysis of data from the Net Zero Insights platform. Please note that aggregated data has not been reviewed by Net Zero analysts.

Commercial landscape

Overview

The fermentation-enabled protein sector consists of a wide range of companies and product types. Biomass, precision, and traditional fermentation utilize distinct production methods, occupy unique spaces within the food industry, and exist in different stages of development.

Each fermentation approach offers a powerful way to diversify the food supply, enhancing its resilience to challenges like supply chain disruptions, such as bird flu outbreaks or extreme weather events. Alternative proteins produced with fermentation can be scaled locally and adapted to a variety of land- and water-constrained environments, adding flexibility and capacity to the food system.

Several key trends occurred across fermentation production platforms and stages of development in 2024. Dairy end-product manufacturers increased engagement in the fermentation sector through high-profile partnerships. Large, diversified companies remained involved in the industry. Many products on the market expanded distribution and ingredients entered new applications, while fermentation-enabled products—from whole-cut steaks to egg proteins—launched. At the same time, investments in fermentation companies showed resilience in an otherwise subdued funding environment.

The sector diversified and expanded in 2024. Highlights from across the fermentation ecosystem are detailed below beginning on page 7.

Understanding fermentation

Several forms of fermentation are being harnessed for alternative protein solutions.

Traditional fermentation has been used for thousands of years to produce familiar products such as bread and beer. It uses intact, live microorganisms to modulate and process plant-derived ingredients, resulting in products with unique flavors, nutritional profiles, and textures. Examples include using the fungus Rhizopus to ferment soybeans into tempeh and using various lactic acid bacteria to produce cheese and yogurt. Traditional fermentation can improve the sensory, functional, and nutritional attributes of many alternative protein ingredients.

Biomass fermentation leverages the high-protein content and fast growth of microorganisms to produce large quantities of protein efficiently. Biomass fermentation offers the greatest opportunity to produce protein at scale, owing to the ability of many microorganisms to grow quickly, often doubling their weight in just a few hours.

Microbial biomass can be the main ingredient of a food product or serve as one of several ingredients in a blend. A range of microorganisms is being explored for their applications in biomass fermentation, from yeast to filamentous fungi to microalgae.

Precision fermentation is a form of specialized brewing that uses microbes as “cell factories” for producing specific functional ingredients. Capable of producing proteins, vitamins, enzymes, natural pigments, and fats, precision fermentation is well-positioned to create high-value ingredients that improve the sensory characteristics and functional attributes of plant-based products or cultivated meat. It can be used to make products like egg proteins, dairy proteins, animal-free meat proteins, including heme, and fats.

Company landscape

- **Number of companies:** In 2024, GFI's company database identified 165 companies focused primarily on fermentation for alternative proteins. Additionally, at least 210 diversified companies to date have joined the industry through investments, partnerships, or business-to-business (B2B) product/service offerings.
- **Along the value chain:** The majority of fermentation companies remain focused on end-product formulation and manufacturing, but there has been an uptick in activity in other areas of the fermentation value chain, like ingredient optimization and bioprocess design.

Fermentation-enabled ingredients allow companies to diversify their supply chains by offering drop-in solutions that improve product sustainability without altering taste or functionality. They also allow companies to leverage ingredients that present a unique value proposition to consumers. The growing number of fermentation companies focused on meeting these needs through B2B operations represents a lasting trend in the space.

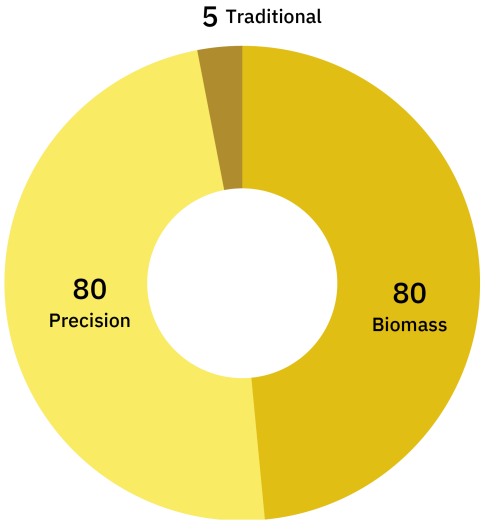
Figure 1. Distribution of specialized fermentation companies by country and region

1–9 companies | 10–19 companies | 20+ companies

Africa and Middle East *Count 19*					
Egypt	1	Israel	15		
Ethiopia	1	South Africa	2		
Asia Pacific *Count 27*					
Australia	5	India	3	Singapore	9
China	5	New Zealand	4	Thailand	1
Europe *Count 70*					
Austria	4	France	7	Spain	
Belgium	5	Germany	11	Sweden	3
Denmark	2	Luxembourg	1	Switzerland	2
Estonia	2	The Netherlands	7	Turkey	1
Finland	3	Norway	2	United Kingdom	14
Latin America *Count 5*					
Brazil	3	Chile	2		
Canada and U.S. *Count 44*					
Canada	4	United States	40		

Source: Good Food Institute, Alternative protein company database, accessed December 11, 2024. Specialized companies include 1) companies primarily or solely focused on producing foods that directly replace animal products (meat, dairy, seafood, or egg analogs) or 2) companies with a significant or sole focus on serving the alternative protein industry with ingredients or equipment. To avoid double counting companies across alternative protein sectors in the State of the Industry reports, companies involved in multiple alternative protein platforms are categorized by the platform they are *most* involved in (e.g., plant-based, fermentation). These restrictions do not apply in GFI's alternative protein company database.

Figure 2. Number of companies by technology focus



Note: Involvement by technology focus area is determined by a company's categorization in GFI's Alternative protein company database. Company representatives can self-select their company's focus area(s), as can GFI team members.

Source: Good Food Institute, Alternative protein company database, accessed December 11, 2024.

Facilities

The growth of the market for fermentation-enabled protein products means more and larger fermentation facilities are essential to increase supply and lower costs through economies of scale.

- **New openings:** At least 16 fermentation facilities opened or were announced in 2024. The majority of the activity occurred in the biomass and precision fermentation sectors, with facilities ranging from pilot to industrial scale.
- **Introducing innovation hubs:** At least five facilities—four in Europe and one in Singapore—were innovation hubs or research & development centers. Three of those facilities focused on precision fermentation, one on traditional fermentation, and one on multiple fermentation methods. Innovation hubs and research & development centers such as these can help companies de-risk processes, demonstrate commercial viability, and reduce scale-up costs.
- **Notable new capacity:** Two industrial-scale precision fermentation facilities in the Middle East—**Novel Foods Group**'s $500 million biotech production hub and **ImaginDairy**'s facility with 100,000 liters of fermentation capacity—promise to add significant capacity to the precision fermentation ecosystem. Opened and upcoming commercial-scale biomass fermentation facilities from **Enifer**, **Kynda**, **MAASH**, **Nosh.bio,** and **Solar Foods** will enable the production of tens of thousands of tons of fermentation-enabled proteins in Europe in the coming years, and **Planted**'s planned facility in Germany will produce upwards of 7,000 tons of fermentation-enabled plant-based meat each year.

Involvement by diversified companies

New activity in the fermentation sector from diversified companies accelerated in 2024. Diversified companies established partnerships, invested in companies and facilities, and debuted new fermentation-enabled products.

Biomass fermentation

- **Nosh.bio** formed a commercial partnership with European sausage producer **zur Mühlen Group** to introduce Koji Chunks to the market.
- New Zealand dairy cooperative **Fonterra** partnered with **Superbrewed Food** and **Nourish Ingredient** to produce functional biomass proteins and fats.
- **Cargill** and **Enough** signed a commercial agreement to use and market Enough's Abunda mycoprotein.
- **Petit Navire** (owned by **Thai Union**) partnered with microalgae startup **Algama Foods** to launch a line of plant-based fish products.

Precision fermentation

In the dairy category:

- **Danone** announced a new precision fermentation technology center in France.
- **Leprino Foods Company** entered a commercialization agreement for **Fooditive Group**'s fermentation-derived casein.
- **Unilever**'s Breyers ice cream brand launched an ice cream made with Perfect Day's whey protein.

Activity in the egg category:

- **The EVERY Company**'s agreements to supply fermentation-enabled egg whites for **Unilever**'s Vegetarian Butcher brand and **Grupo Empresarial Palacios Alimentación**'s omelet products.
- **Nestlé** launched a protein powder made with **Perfect Day**'s whey.

Traditional fermentation

- Dairy company **The Bel Group** invested €7.5 million to expand its Research, Innovation, and Development (RID) center in Vendôme, where one of its projects will focus on developing fermented and plant-based cheese alternatives.
- South Korean food company **Namyang Dairy Products** partnered with **Pureture** to produce products using Pureture's yeast-based casein made using liquid fermentation.

By leveraging their funding, infrastructure, and distribution networks, diversified companies can serve as a force multiplier for the fermentation sector. Fermentation-enabled alternative proteins provide companies with additional sources of key inputs and encourage cost competition. Integrating these products into supply chains increases companies' resilience to market shocks, broadens risk management opportunities, and promotes long-term input cost stability.

Photo credit: Vivici

Table 1. Diversified company involvement in fermentation

✓ Previous activity ✓ New 2024 activity

	Investment	Acquisition	Partnership	R&D and manufacturing
ABInBev	✓		✓	✓
Bel Group			✓	✓
Cargill			✓	
Cheil Jedang Corp			✓	
Danone	✓			✓
Fonterra			✓✓	
Friesland Campina				✓
General Mills			✓	✓
Grupo Empresarial Palacios Alimentación			✓	
Hormel Foods			✓	
KraftHeinz	✓			
Leprino Foods Company			✓	
Maple Leaf	✓		✓	
Namyang Dairy Products			✓	
Nestlé	✓			✓
Pulmuone			✓	
Tyson	✓			
Unilever			✓	✓
zur Mühlen Group			✓	

Source: GFI analysis of publicly reported industry news and events.

New partnerships

At least 21 partnerships were formed in the fermentation sector in 2024, with especially robust activity in dairy product development and commercialization, seafood product development, and process optimization.

- **Dairy:** Partnerships in the dairy category included the previously mentioned engagement from **Bel Group**, **Fonterra**, **Leprino Foods**, and **Namyang Dairy Products**.
- **Seafood:** French seafood brand **Petit Navire** (owned by **Thai Union**) teamed up with microalgae producer **Algama Foods** to introduce a new line of plant-based fish products. **Revo Foods** and **Paleo** joined forces to develop plant-based salmon alternatives enriched with precision-fermented myoglobin for enhanced taste and functionality. **Mara Renewables** partnered with **Checkerspot** to accelerate the commercialization of omega-3 fish oil substitutes. In the U.S., **Aqua Cultured Foods** tapped **Ginkgo Bioworks** to refine the production of its fermentation-derived whole-cut seafood, signaling further advancements in sustainable seafood innovation.
- **Process optimization:** Biomass and precision fermentation companies partnered with technology, equipment, cultivated fat, and diversified food companies to reduce costs and optimize processes.

Dairy end-product manufacturers, in particular, are recognizing fermentation's unique ability to efficiently produce functional ingredients, as several large conventional dairy companies partnered with fermentation companies in 2024. These partnerships offer fermentation production platforms increased viability in the marketplace and provide a clearer pathway to large-scale production.

Photo credit: ImaginDairy

Product launches

Startups and large consumer packaged goods (CPG) companies launched fermentation-enabled products that spanned production platforms, product types, and regions in 2024.

- **Biomass fermentation:** Biomass fermentation companies launched meat and seafood end products, including new mycoprotein products in Europe from **Schouten Europe** and **Quorn** and a mycelium fish filet in South Korea from **Koralo**. Dairy product introductions included a U.S.-wide launch of fungi-based yogurt from **Nature's Fynd**, **Protoga Biotech**'s microalgae milk in China, **Solar Foods**' dairy replacement proteins in select **Ajinomoto Group** products, and **Cultivated Biosciences**' yeast-based fermented fat in a coffee creamer prototype. **FrieslandCampina** also launched a powder made of microencapsulated algae-based ingredients for plant-based products.
- **Precision fermentation:** In addition to the previously mentioned ice cream and protein powder product launches from **Unilever** and **Nestlé**, **Bored Cow** launched animal-free milk and yogurt products made with **Perfect Day**'s whey protein in stores across the U.S., and **The EVERY Company** introduced a liquid egg product containing fermentation-derived ovalbumin.

Curious about the latest information on alternative protein trade organizations? Take a look at a list of alternative protein industry organizations here.

- **Traditional fermentation:** In the traditional fermentation space, **Chunk Foods** launched its fermentation-enabled whole-cut plant-based meat products in U.S. retail, marking the company's first direct-to-consumer availability.
- **Blended meat:** UK-based mycoprotein meat brand **Quorn** partnered with the **National Health Service** of the UK to add blended meat products to hospital menus, where Quorn's mycoprotein will be mixed with conventional meat to create blended burgers, sausages, and other meat. **Mush Foods** launched its 50CUT mycelium blends in the U.S. foodservice market following a B2B launch of their mycelium ingredient in Israel.

Fermentation-enabled products demonstrated versatility and increased availability in 2024 with launches across various channels, categories, and regions, providing more consumers than ever the opportunity to try meat, dairy, and egg products made with fermentation.

> For a deeper dive into 2024's alternative protein industry news, check out previous editions of GFI's Alternative Protein Opportunity newsletter.

Investment

Overview

Since the first disclosed investment in a fermentation company in 2013, privately held companies in the sector have raised $4.8 billion, while publicly traded companies have secured $39 million. In 2024, the fermentation sector attracted $651 million in total funding, all of which was raised by privately held companies.

The wider ecosystem of companies involved primarily in alternative proteins brought in $18.6 billion in funding from 2015 to 2024—$16 billion raised by privately held companies and $2.5 billion secured by publicly traded firms. In 2024, privately held alternative protein companies raised $1.1 billion. The slowdown in funding followed the trend in the broader climate tech sector, which also experienced consecutive annual funding declines since 2021. While the broader venture funding sector experienced slight growth in 2024, the increase was primarily due to the rise in artificial intelligence (AI) funding, which rose to nearly $100 billion in 2024 and may have redirected capital flows from other industries.

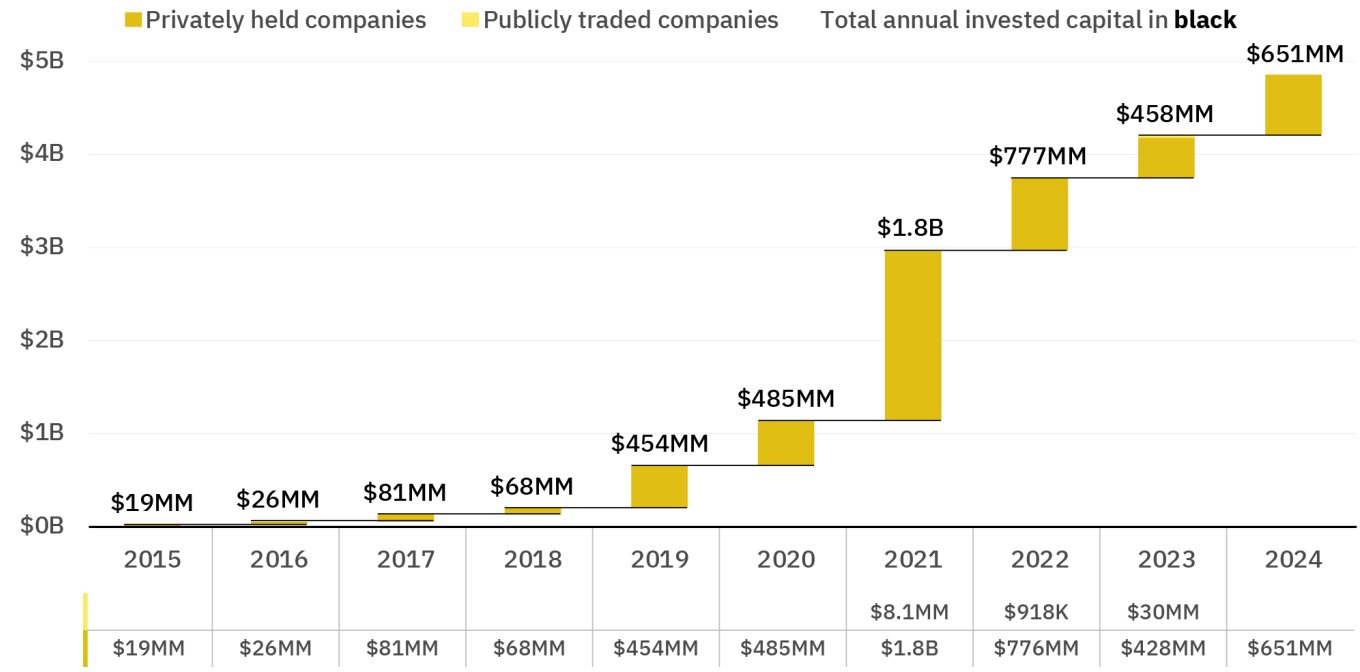
In recent years, the broader investment environment (particularly elevated interest rates), uncertain scale-up timelines, and high production and materials costs slowed the flow of capital into the alternative protein sector, resulting in fewer companies receiving smaller quantities of funding.

Despite these headwinds, investments in fermentation companies demonstrated relative resilience. Fermentation funding totals increased year-over-year in 2024, with investors drawn to fermentation-enabled products' functionality, high consumer favorability, compelling B2B propositions, and increased government support. Still, fermentation companies need access to more resources to expand product variety, increase scale, and implement process improvements.

Venture capital is only one piece of the funding puzzle, and fermentation companies must continue to pursue creative and multipronged funding strategies to access the capital needed for the industry to achieve scale.

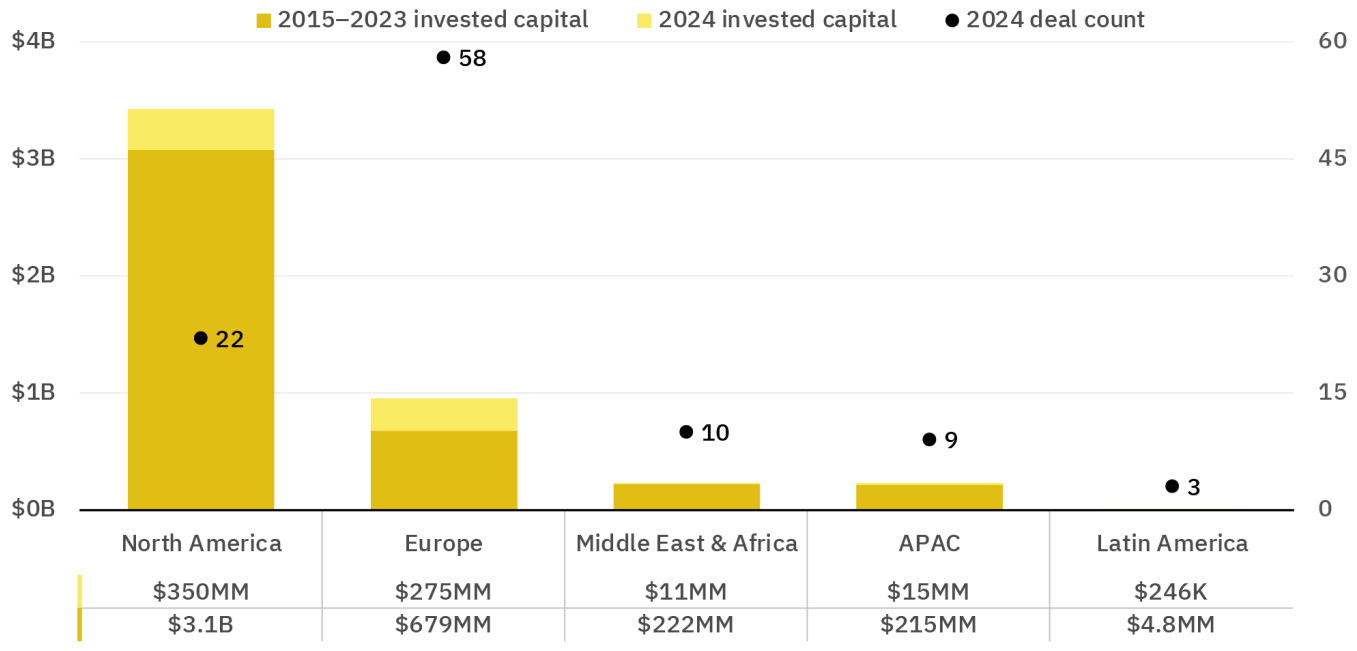
- **Significant deals:** The four largest fermentation deals in 2024 were **Meati**'s $100 million Series C, **Perfect Day**'s $90 million Series E, **Formo**'s $61 million Series B, and **Infinite Roots**' $58 million Series B.
- **The long-view context:** Of the top four fermentation deals in 2024, only **Meati**'s ranks among the all-time top 10 largest investments in the fermentation sector. The investment environment of the past two years has been fundamentally different from the low-interest-rate period of 2019 to 2022, when the other nine largest fermentation rounds were raised.
- **Difficult venture capital environment:** Amid an overall decline in climate tech investments, food, agriculture, and land use was only 8% of venture funding in climate tech in Q4 2023 through Q3 2024 despite comprising 22% of global emissions.

Figure 3. Investment in privately held and publicly traded fermentation companies
2015–2024



Source: GFI analysis of data from Net Zero Insights. Aggregated data has not been reviewed by Net Zero Insights analysts. Note: Fermentation totals include investments in both privately held and publicly traded companies.

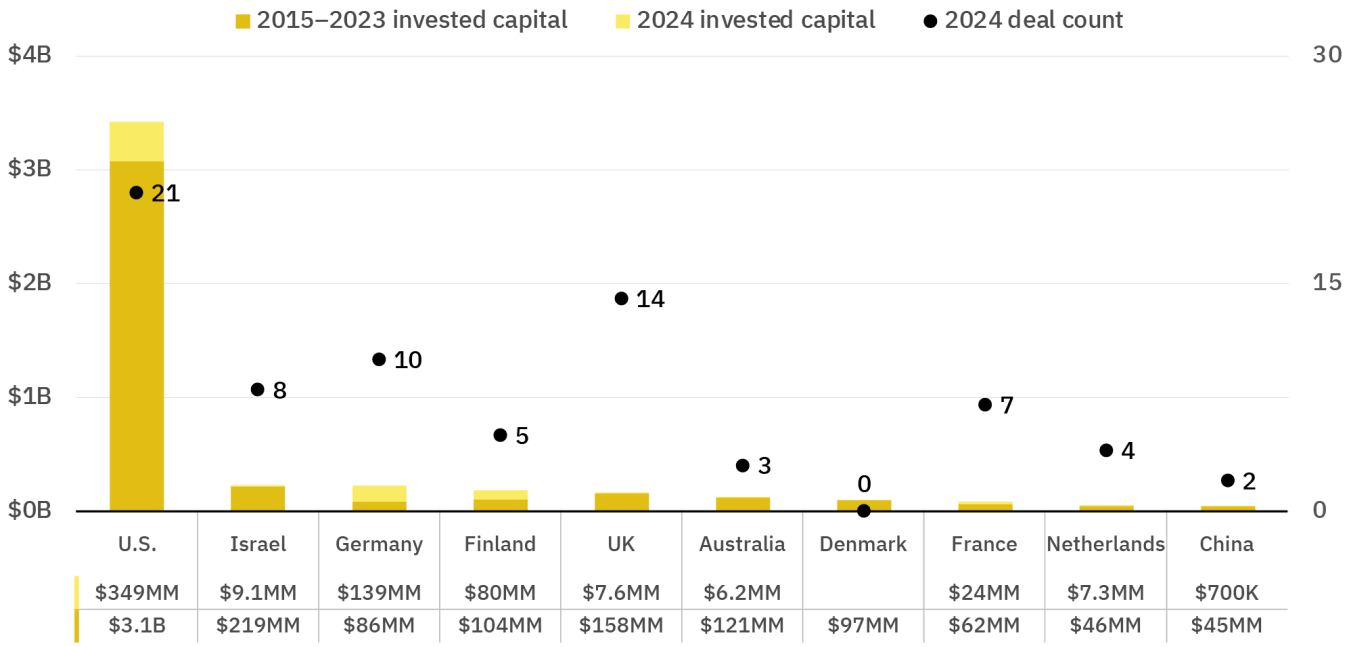
Figure 4. Investments in fermentation by region
2015–2024



Source: GFI analysis of data from Net Zero Insights. Aggregated data has not been reviewed by Net Zero Insights analysts.
Note: Fermentation totals include investments in companies focused primarily on plant molecular farming due to similarities in the types of ingredients they produce and in the downstream processing to obtain those ingredients from the host organisms. Fermentation totals include investments in both privately held and publicly traded companies.

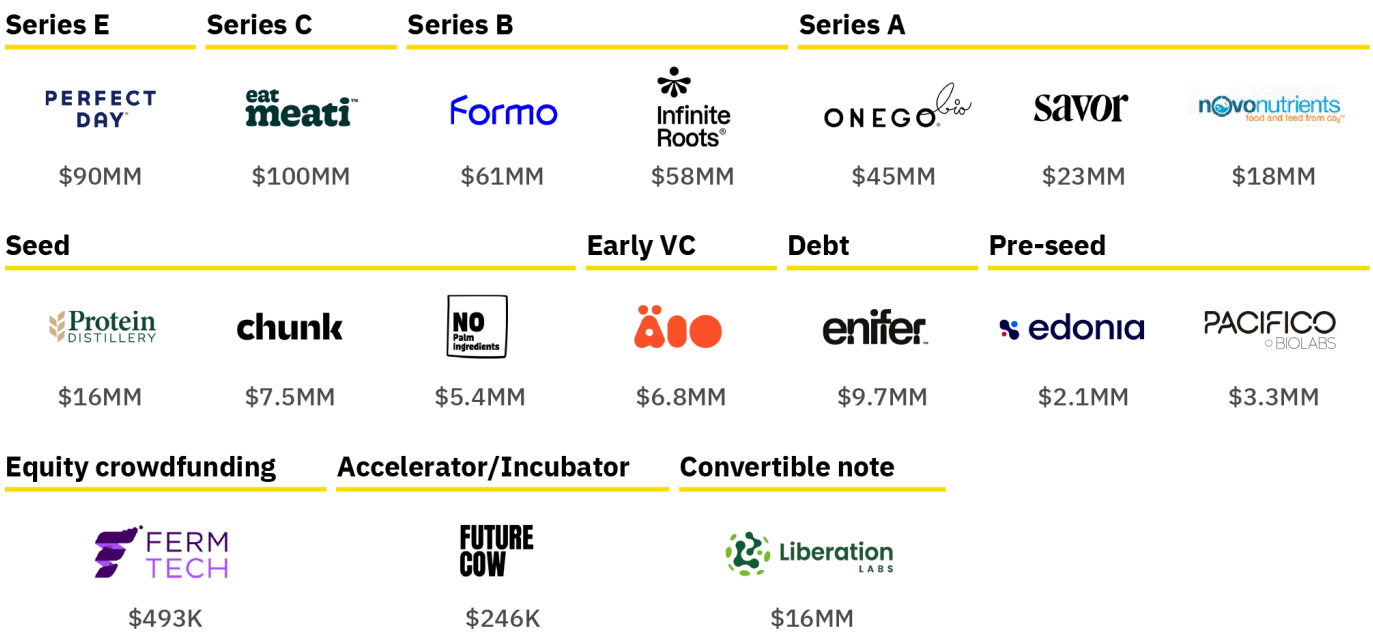
Figure 5. Investments in fermentation: Top 10 countries

2015–2024



Source: GFI analysis of data from Net Zero Insights. Aggregated data has not been reviewed by Net Zero Insights analysts.
Note: Fermentation totals include investments in companies focused primarily on plant molecular farming due to similarities in the types of ingredients they produce and in the downstream processing to obtain those ingredients from the host organisms. Fermentation totals include investments in both privately held and publicly traded companies.

Figure 6. 2024 key funding rounds



Source: GFI analysis of data from Net Zero Insights. Note: "2024 key funding rounds" includes investments in the 75th percentile or higher by dollar amount for each funding round category that includes more than three deals. For funding round categories that include three deals or fewer, all deals are included. Aggregated data has not been reviewed by Net Zero Insights analysts. The total deal count includes deals with undisclosed amounts.

Key trend #1: A tight capital landscape

The private funding landscape for fermentation differs from a few years ago. Global interest rates are elevated relative to recent years' lows, and investors have now had several years to track the industry's evolution. Investors are demonstrating more discretion in allocating funding but have shown a sustained appetite for attractive deals in fermentation companies.

Investments going forward will likely be distributed to fewer companies and in smaller quantities than during 2020 to 2022, but fermentation startups seem well-positioned to capture a sizable share of food tech funding in the years ahead.

Successful exits for fermentation companies—or even alternative proteins more broadly—could lead to a meaningful increase in category-wide private capital flows. Until that point, fermentation investments will likely remain closer to the levels seen in recent years. Even if the venture market shifts, it is unlikely to soon return to the peak environment of 2021, which was driven by an extended period of near-zero and even negative interest rates following the 2008 financial crisis. Additionally, while that investment environment spurred some venture funders to support capital expenditure projects, venture capital is not typically well-suited to fund new facilities. As a result, companies looking to scale, especially via first-of-a-kind facilities, will likely need to identify alternative sources of funding.

Key trend #2: Various funding sources needed to fuel sector growth

Given fermentation's current stage of development and the significant capital required to scale, venture funding alone is unlikely to fully support the industry's growth. To achieve long-term viability, fermentation companies will need to complement venture capital with additional funding sources.

It is more important than ever that companies, investors, governments, and philanthropists develop innovative funding solutions that support the growth of the fermentation industry. GFI's Funding the build report, published in 2024, explored potential avenues for companies looking to scale, such as equipment leasing, strategic partnerships, sovereign wealth funds, blended finance, and government programs. Still, there are no silver bullets to fill funding gaps in the fermentation sector.

Fermentation-enabled alternative proteins hold the potential to improve food security, reduce emissions, and protect public health. To realize these outcomes, fermentation companies need more funding, and governments, investors, and philanthropists have the opportunity to work together—as has been done for clean energy development—to position the sector for long-term success.

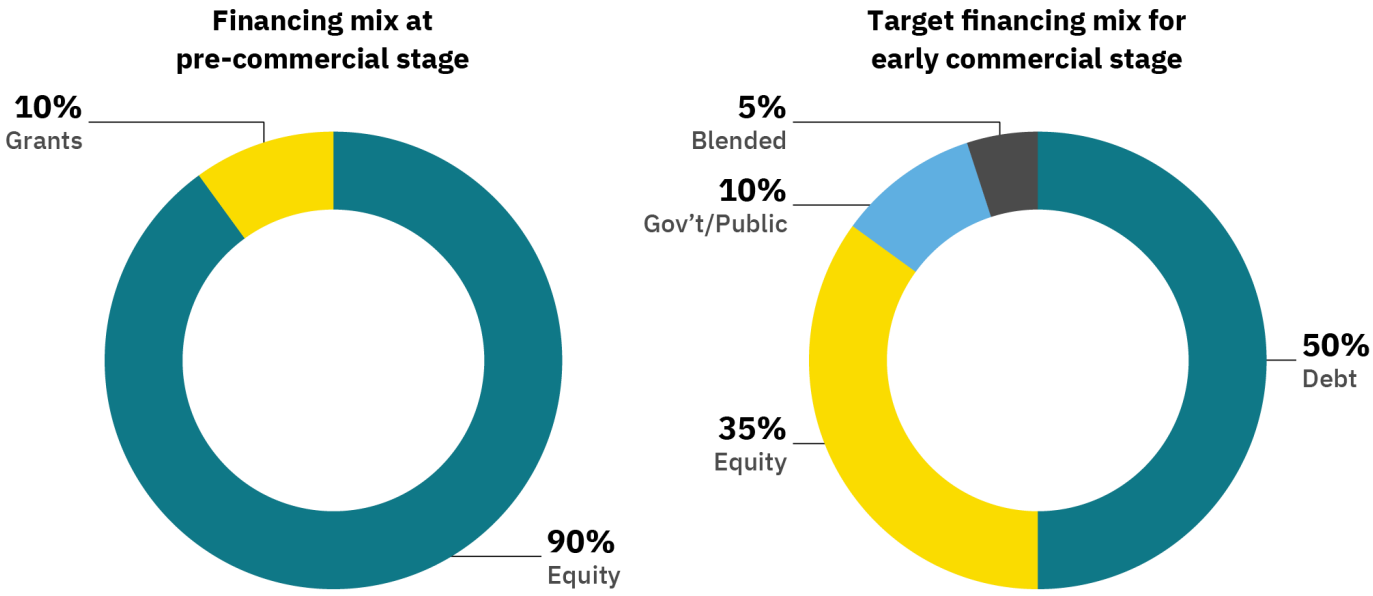


Figure 7. Source: Mixed funding sources example by GFI, first published in Funding the build.

Key trend #3: Consolidation in the sector

Despite the relatively resilient funding totals for fermentation companies, adapting to the new investment environment will take time. Some manufacturers may be unable to secure funding and may downsize, close operations, or merge with other organizations.

This was the case for a handful of companies in 2024, but consolidation should not be equated with a declining category. Consolidation is inevitable for any nascent sector, and mergers, acquisitions, and intellectual property transfers can accelerate the dissemination of technology and expertise within an industry.

In 1909, there were more than 250 automobile manufacturers in the U.S., a number that dropped to fewer than 50 by 1930 as the industry matured. Financial, regulatory, and cost challenges remain for fermentation, but lessons from other industries show that growth can be a long and winding road. The sector's progress should be judged on multiple factors—such as product taste, price, accessibility, and consumer acceptance—rather than the trajectory of private funding alone.

Source: Unless otherwise cited, the investment data reported above was derived from GFI's analysis of data from Net Zero Insights. Note: Aggregated data has not been reviewed by Net Zero Insights analysts. The total deal count includes deals with undisclosed amounts. The Good Food Institute is not a licensed investment or financial advisor, and nothing in the State of the Industry report series is intended or should be construed as investment advice.

Consumer insights

Overview

While protein products made from fermentation have been available in some markets for decades, companies have diversified and innovated in recent years. In 2024, new research was released on how consumers in key regions view these products. This research suggests that many types of fermentation-enabled proteins are novel to consumers and that different types and numbers of consumers will be more open to some types of products. The industry will need to work to build consumer awareness of products and to articulate what they are and their unique benefits, but research suggests these products will appeal to significant numbers of consumers in many regions.

Photo credit: Sergey Ryzhov/Shutterstock.com

How many people know about fermentation-enabled proteins?

Products made from fermentation are one of the longest-standing segments in alternative proteins. Biomass fermented mycoprotein products like Quorn have been available in North American and European markets for decades. At the same time, both mycoprotein and precision fermentation remain new to consumers in many regions. In 2024, research from Europe and the United States shed new light on levels of consumer awareness.

- **U.S. consumer awareness:** Awareness varies for different types of fermentation-enabled proteins. In a 2024 poll by Morning Consult on behalf of GFI, 27% of U.S. consumers recalled having "seen, read, or heard" about "meat made from mushrooms and fungi," 13% "precision-fermented dairy," and 12% "meat made from mycoprotein." A total of 16% claimed to have tried meat made from mycoprotein after the term was defined. These do not suggest an increase from levels seen in 2023.
- **European consumer awareness:** For precision-fermentation-enabled proteins, non-GFI research from 2024 similarly finds low levels of awareness in some regions. A survey in the United Kingdom and United States found 14% of consumers in the UK and 23% in the U.S. were "familiar with precision fermentation." In a survey of German consumers, 81% had never heard of "animal-free dairy" before.

While awareness of mycoprotein as a concept is low, many products made from it are available in these markets and have performed well commercially while marketing on a variety of terms (mycoprotein, mycelium, plant-based, etc.). While consumer education would likely help build awareness of mycoprotein and its benefits, this suggests that multiple ways of explaining the category have been successful.

On the other hand, precision fermented proteins are less widely available and present distinct marketing opportunities and challenges, making it important for companies offering precision fermented products to articulate to consumers both what these products are and what benefits they offer to build awareness and demand.

GFI and Accenture conducted research on consumers in five North American and European countries (France, Germany, Spain, UK, and U.S.) to understand how consumers respond to different names for the category and articulations of its benefits:

- Consumers in most countries preferred "animal-free" as a descriptor, but their degree of preference and which alternatives they preferred varied widely.
- Consumers tended to prefer medium-length descriptions of how precision fermented products are made over longer ones, which poses potential challenges for consumer education.
- How appealing consumers found the concept of precision fermentation and products made from it varied widely across countries, with those in Spain most open and those in France least.
- Consumers' top expected motivations for trying precision-fermented products were diverse, with French consumers most motivated by novelty, German and UK consumers by animal welfare, and Spanish and U.S. consumers by health.

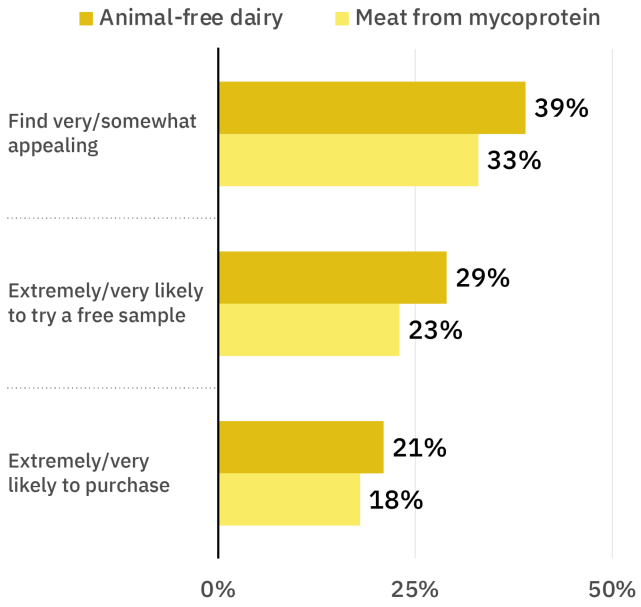
Photo credit: Sergey Ryzhov/Shutterstock.com

GFI APAC explores communications strategies for precision fermentation companies

The novel benefits of precision fermented proteins present both opportunities and challenges for building consumer awareness and familiarity. GFI APAC, in collaboration with more than a dozen industry partners from across the region, published a communications guide offering insights on:

- Distinct benefits of category terms like precision-fermented, fermentation-derived, and animal-free.
- Communications strategies to clarify consumer questions and needs around pricing, sustainability, food safety, allergenicity, GMO status, and more.

Figure 8. U.S. consumer outlook on fermentation-enabled proteins
2024



Source: Survey by Morning Consult on behalf of GFI of 2,214 U.S. adults, May 2024.

How many people are likely to try and buy fermentation-enabled proteins?

Research on U.S. consumers suggests that a minority of consumers are likely to try and buy fermentation-enabled proteins today, while results from Europe suggest higher openness.

U.S. consumer perceptions

In a 2024 poll by Morning Consult on behalf of GFI:

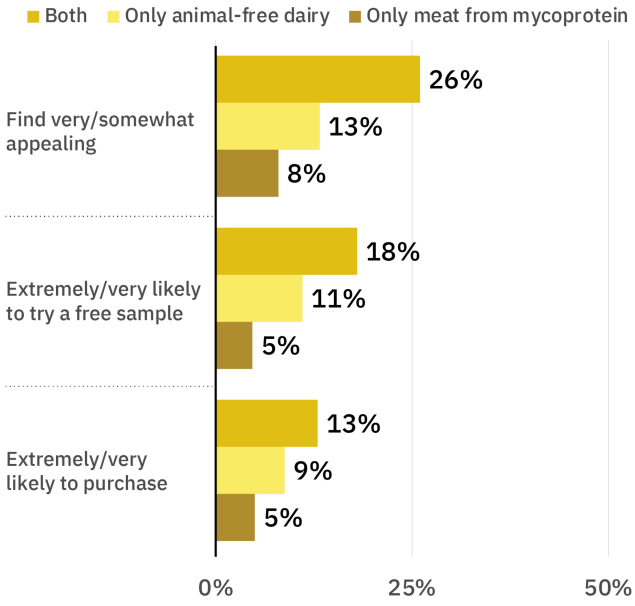
- 39% of U.S. consumers found animal-free dairy "very" or "somewhat" appealing, and 33% felt that way about meat from mycoprotein.
- 29% would be "extremely" or "very" likely to try animal-free dairy if offered a free sample, and 23% would likewise try meat from mycoprotein.
- 21% would be "extremely" or "very" likely to purchase animal-free dairy, and 18% would similarly purchase meat from mycoprotein.

These results likely reflect low levels of consumer familiarity: GFI and Accenture's research on precision fermentation in Europe and the U.S. found more than 50 percent of consumers across these regions on average would be willing to try precision fermented dairy and eggs after learning about these products.

Differences between "likely" mycoprotein and precision-fermented consumers

While most consumers who rated these products as appealing (or said they were likely to try or buy them) said so for both, a significant number said so for animal-free dairy but not mycoprotein. These groups were not demographically distinct from each other (both tended to be younger, more male, and more urban). This suggests that different fermentation-enabled proteins may appeal to different segments of consumers based on attitudinal or perceptual differences, and will be relevant to the industry when bringing products to market.

Figure 9. U.S. consumers shared and separate interest in types of fermentation-enabled proteins
2024



Source: Survey by Morning Consult on behalf of GFI of 2,214 U.S. adults, May 2024.

Receptivity to different fermentation products: Research by McKinsey on consumer interest in alternative proteins—including ones made with various fermentation types and with various names—found that:

- Around two-thirds of consumers are willing to try animal-free (precision fermented) products.
- Between two-thirds and half of consumers are willing to try biomass fermentation products (prebiotic, cultured, postbiotic, fermented, etc.), depending on how they are described.
- Around half are willing to try proteins naming fungi or fungal ingredients ("nutritional fungi protein," "mycelium protein," "mycoprotein").

European consumers: Several studies on Northern Europe published in 2024 suggest higher levels of consumer openness.

- A survey of German consumers found 57% willing to try "animal free cheese."
- A survey of Danish consumers found approximately 4 in 10 willing to "[consider] the purchase of these products." They found comparable levels of likelihood for 3 fermented product categories tested: "indulgent" (cookies, chocolate, etc.), "functional" (milk, cheese, and yogurt), and "enriched" (including protein bars, drinks, and powders), which ranged from 2-to-3 in 10. Consumers under the age of 35 were much more likely to consider them (45%, more than twice as high as consumers 35 and over).

While this data reflects consumer openness to products where fermentation-derived ingredients are positioned as the bulk of the product formulation, they can also play a role in shaping the sensory properties of products that will be key for driving consumer interest and adoption. For example, **Impossible Foods**' soy leghemoglobin, which accounts for their beef products' "bleeding" behavior, is produced through fermentation, and companies in the U.S. and EU are pursuing commercialization for precision fermented fats that can shape the mouthfeel and melting properties of plant-based foods.

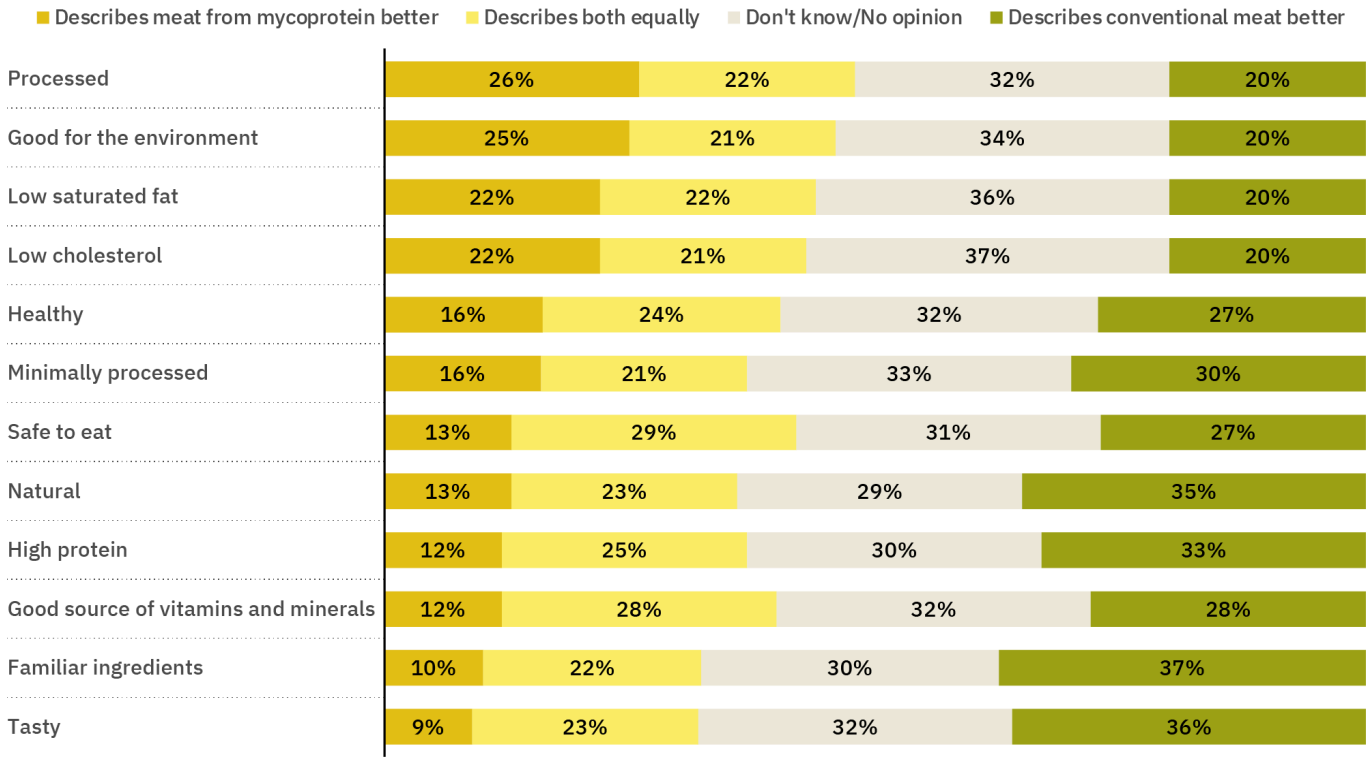
What will lead people to try and buy fermentation-derived proteins?

Different types of fermentation-enabled protein products can claim unique benefits in the context of the alternative proteins market. For example, many mycoprotein products available today offer clean labels and short ingredient lists, while precision fermented products can be made with ingredients that are the same as those found in animal products, and many consumers associate fermented foods with digestive and gut health, which were increasingly important to consumers in 2024 according to the International Food Information Council's annual survey.

U.S. consumer perceptions

Based on GFI and Morning Consult's 2024 poll of U.S. consumers, many consumers see both these types of fermented proteins as "good for the environment," low in nutrients like cholesterol and saturated fat, "safe to eat," and "healthy." Fewer rate them as "natural," their ingredients as "familiar," or expect them to be "tasty."

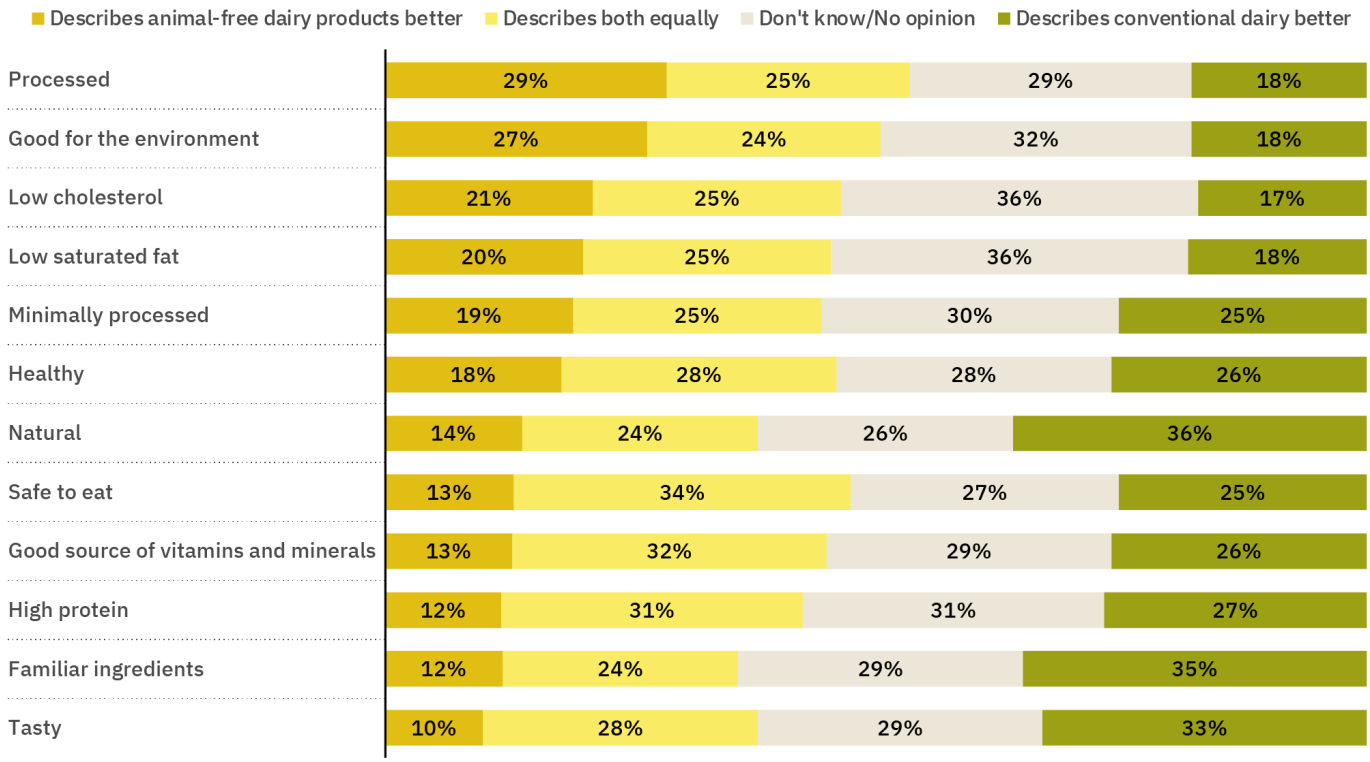
Figure 10. Product benefits expectations for meat from mycoprotein compared to conventional meat



Question: "In your opinion, do each of the following attributes describe mycoprotein or conventional meat better?"

Source: Survey by Morning Consult on behalf of GFI of 2,214 U.S. adults, May 2024. Note: This figure shows the percent of survey respondents who expect each type of mycoprotein to be better than, or the same as, conventional meat in a given category. n=1,124 saw "minimally processed," n=1,090 saw "processed."

Figure 11. Product benefits expectations for precision-fermented dairy compared to conventional dairy



Question: "In your opinion, do each of the following attributes describe animal-free dairy or conventional dairy better?"

Source: Survey by Morning Consult on behalf of GFI of 2,214 U.S. adults, May 2024. Note: This figure shows the percent of survey respondents who expect animal-free dairy to be better than, or the same as, conventional dairy in a given category. n=1,124 saw "minimally processed," n=1,090 saw "processed.

European consumer perceptions

Research on Danish consumers found similar perceptions. Many associate precision fermentation with being "artificial" and "unnatural" but with health benefits such as "protein" and "health." And participants often "linked precision fermentation with positive environmental aspects and animal well-being."

Similarly, a survey of German consumers found that consumers exposed to a description of the environmental and product consistency benefits of precision fermented cheese rated themselves as more likely to try and buy it than those exposed to alternate explanations or ones that omitted those benefits.

In 2024, GFI Consultancy, GFI's independent strategic partner in China, conducted China's first consumer perception study on biomass fermentation proteins. While plant-based meat analogs have struggled to gain traction in China despite the ubiquity of traditional plant-based proteins like tofu, biomass fermentation is emerging as the next wave of protein innovation, offering unique opportunities. This study analyzed consumer perceptions of conventional proteins, and their attitudes and acceptance of biomass fermentation proteins, providing communication guidelines for the industry. See GFIC's resource page for more insights.

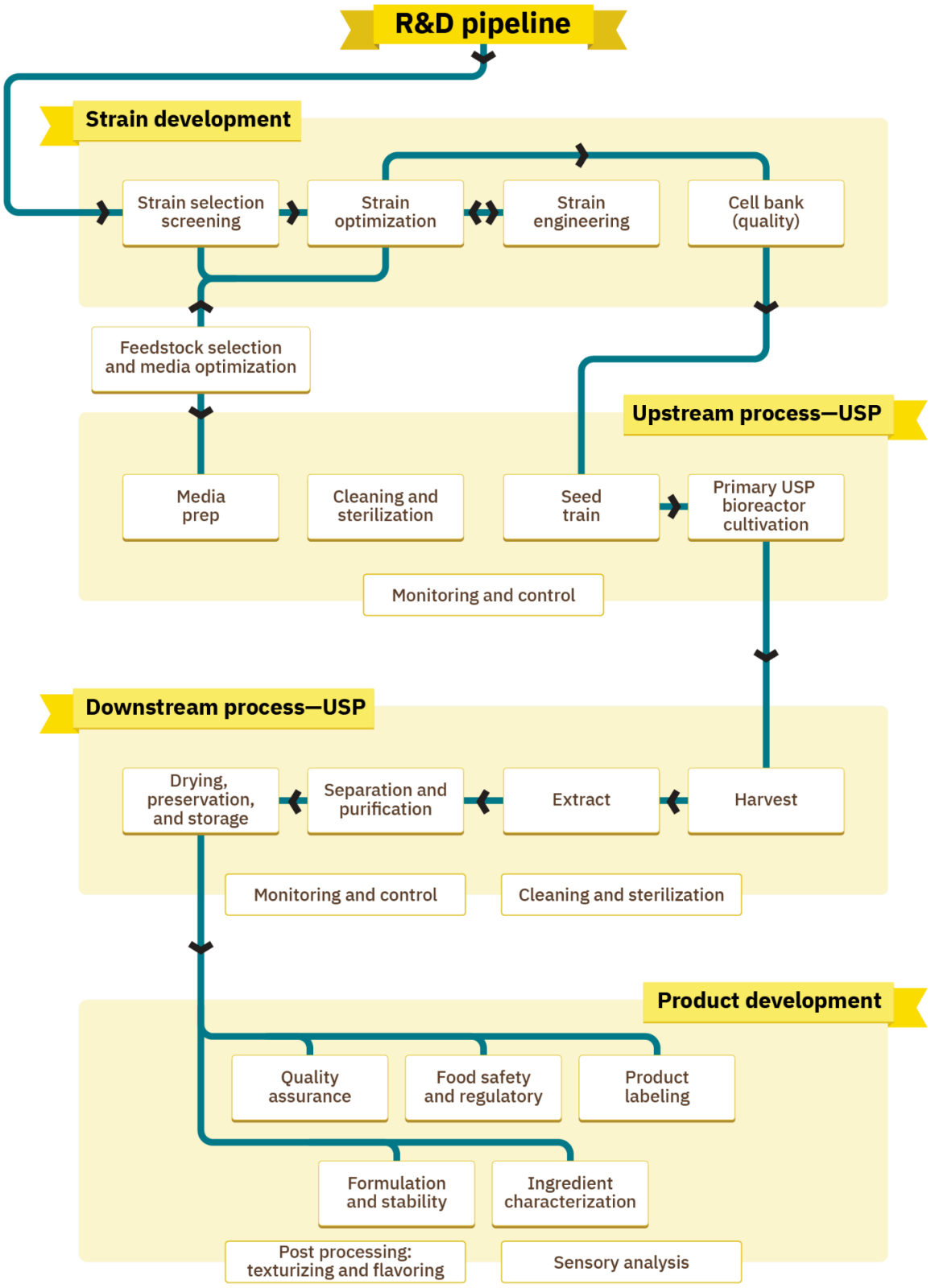
Science and technology

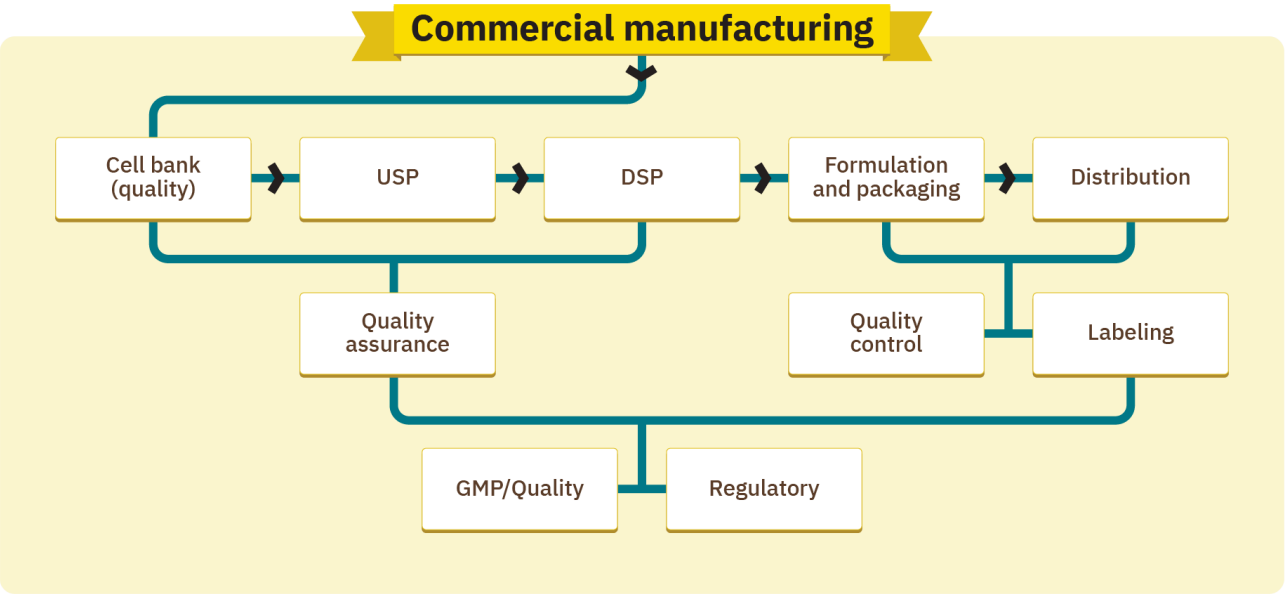
Overview

In 2024, fermentation researchers harnessed diverse microbial strains, optimized growth, and fine-tuned ingredient isolation to create sustainable products. These updates showcase the range of R&D and commercialization efforts across the value chain. Several themes emerged:

1. **Biomass ingredients offer varied end-product benefits** through innovations that unlock production cost savings and application opportunities. Nutritious protein sourced from diverse microbes and bioprocesses can enhance meat-like taste, texture, and functionality, while alternative feedstocks enhance cost efficiency.
2. **Precision fermentation producers continued to iteratively increase efficiency.** They achieved this with multifold titer improvements, novel formulations, encouraging process validation, and intellectual property milestones. These ingredients' functionality (e.g., gelling, binding, umami taste) and nutrition (e.g., high protein digestibility, healthy fat inclusion) can suit diverse consumer needs.
3. **Fermentation-derived ingredients are increasingly developed for tailored functionality** rather than direct substitution. Suppliers are focusing on higher-value targets and optimizing key functionalities like solubility, gelation, and emulsification, which can unlock higher-value applications or enhance performance, reduce inclusion rates, and decrease cost-in-use.
4. **Efficiency enables scaling and drives sustainability.** Economic wins in resource utilization, higher titers, and using waste carbon are also sustainability wins. Retrofitting a brewery, capturing carbon off-gas as feedstock, or valorizing spent grains can cut expenses while also reducing emissions.
5. **Leveraging collaboration advances the pipeline.** The global food system demands increased fermentation capacity. A collaborative ecosystem fosters innovation and knowledge-sharing, and consortia and public investment support scaling research into commercialization.

Figure 12. Fermentation value chain map





Source: Modified from GFI APAC, "Career Pathway," (Dec. 2024).

Fermentation R&D innovation addressed broad functional needs with diverse strains and feedstocks

Biomass

Fermentation biomass from filamentous fungi (mycoprotein) and yeast, bacteria, and algae (single-cell protein, SCP) can deliver large quantities of nutritious and functional protein with the microorganisms minimally processed or intact.

Advances in mycoprotein production and formulation centered around filamentous fungi strain development and alternative feedstocks.

Filamentous fungal protein (mycoprotein)

Filamentous fungi offer robust strain, bioprocess, and formulation opportunities

Filamentous fungi and mycelium comprise diverse molds and mushrooms traditionally used to produce tempeh and other fermented foods. In 2024, filamentous fungi edged forward in formulation, shelf-stability, and as ingredients for blended or hybrid products:

- **Biomass formulation process advances:** Producers from **Marlow Foods**, **Nature's Fynd**, and **Meati** advanced formulation techniques with alternative binding ingredients, texturization methods, liquid air interface processes, and downstream separation and forming processing, widening the options for manufacturing alternative products.
- **Shelf-stability improvements**: **The Better Meat Company**'s shelf-stable *Neurospora* mycoprotein can be combined with conventional meat, a breakthrough product with a regulatory green light from this fungi strain, opening doors for potential in blended meat product development.
- **Functional ingredient development: UC Berkeley** and **DTU Biosustain** researchers developed a heme expression system in *Aspergillus oryzae* to color the biomass red and improve the taste for a more meat-like sensory experience. **Nosh Bio** developed dehydrated and alkaline-hydrolyzed *A. oryzae* biomass, delivering a remarkable meat-like texture. **CJ CheilJedang** and **Aqua Cultured Foods** optimized mycelium for nutrition and texture by including all essential amino acids or co-culturing it with bacteria for alternative seafood.

> ✦ *Key takeaway*
>
> Fungi like *Neurospora* and *Aspergillus* have a long history of safe use, functionality, and nutrition. These developments signal these species' utility as nutritious options for single-ingredient meat alternatives, while innovating on novel formulations to improve the taste, texture, and appeal of mycoprotein alternatives.

See GFI's Science of Alt Protein presentation on the potential of traditional fungi and Dr. Leonie Jahn (GFI grantee, 2024 Nils Foss Talent Prize winner) on microbial biodiversity in the green transition.

Fungi are increasingly recognized for their ability to valorize sidestream feedstocks

By leveraging food-safe fungi's natural fermentation capabilities, there is potential to transform available food and agriculture byproducts into sustainable food sources, reducing waste and enhancing food security. In 2024, feedstocks' commercial viability continued to progress.

Spent grain

As high-volume sidestreams of brewing and distilling industries, spent grains are a plentiful, nonseasonal, and centralized feedstock. Groups from **Jiangnan University and Wageningen University**, **Agro Ludens Inc.**, and **Infinite Roots** explored spent grain for solid-state and submerged fermentation.

Upcycled food waste

Indonesia International Institute for Life Sciences scientists examined soybean processing sidestreams for *A. oryzae* while **University of California Davis** researchers used a different *Aspergillus* strain for high-protein biomass growth on sugar from almond hulls, another abundant byproduct. **Aberystwyth University** researchers developed a solid-state fermentation process to upcycle bread waste using *Rhizopus oligosporus,* traditionally used in tempeh production.

Mycelium cultivation on sidestreams

Technical University of Denmark researchers produced *Pleurotus ostreatus* (oyster mushroom) mycelium from sugar beet pulp waste, while **Infinite Roots** developed *Pleurotus pulmonarius* (Phoenix oyster mushroom) mycelium grown on spent grains. **Mycotechnology**'s now patent-protected process uses mushroom mycelium, like *Pleurotus sp.*, to increase the protein quality and improve the taste and aroma of pea protein, soy protein, and low-grade corn gluten meal.

> ✦ *Key takeaway*
>
> Feedstocks are one of fermentation's primary economic and environmental impact drivers. Thankfully, there are diverse options and emerging strain choices, like mushroom mycelium and filamentous fungi, that can upcycle common and accessible industry byproducts.

See GFI's post on sustainable fungal protein, sidestreams, and manufacturing and our 2023 sidestreams analysis, which identified spent grain and corn gluten meal as top candidates.

Single-cell protein

Biomass fermentation output can be purified into distinct ingredients like protein concentrates or used directly as whole single-cell protein (SCP). Innovations in SCP and microbial protein flours showed commercialization traction for yeast, microalgae, and bacteria in 2024.

Rethinking yeast protein processes and formulation can deliver on taste

Yeast SCP has a longstanding use as a nutritional and flavoring ingredient. In 2024, renewed interest in yeast SCP's high protein concentration and desirable functionalities spurred further development.

- **Umami flavor**: Yeast protein often provides meat-like umami flavor. **Beijing Technology and Business University** and **Ocean University of China** researchers identified novel umami peptides from yeast protein through enzymatic, sensory, and in silico approaches. Understanding peptide composition can shed light on the complex relationship between flavor and these short, yet critical, protein sequences.
- **Protein extraction and texturization**: Unlocking yeast SCP taste opportunities requires efficient protein extraction and texturization. **Kongju National University** developed a process for improving formulation by including yeast SCP in extruded hybrid plant-based meat, while **Yeap Ltd** developed an efficient and simple procedure for extracting protein concentrates from yeast, tailored for meat alternatives.
- **Functional advantages**: Companies also explored upcycled brewer's yeast SCP to provide unique functional advantages. **Revyve**'s patent-pending process generates upcycled brewer's yeast protein with improved emulsification, foam stability, gelation, and water holding capacity as an egg replacement or for plant-based meat. **ProteinDistillery**'s patent-pending extraction process produces an ingredient with promising binding capabilities comparable to methylcellulose.

✦ Key takeaway

Yeast SCP is a familiar, nutritious, and cost-efficient ingredient with natural umami flavor. In 2024, researchers advanced yeast SCP gelling and binding properties, enhancing its functional utility as a valuable high-protein ingredient with more potential to improve the realistic texture of meat and egg alternatives.

Microalgal SCP offers nutritious, functional ingredients with flexible bioprocesses

With high-protein content and healthy lipids, like omega-3s, microalgae biomass can serve as a source of protein, fat, or both. Additionally, microalgae are rich in vitamins and nutrients like carotenoids. Microalgae biomanufacturing has previously been scaled, providing confidence in the commercial viability of innovations. Recent developments include:

- **Functional ingredients have multiple applications: Corbion** has patented microalgal flours with high-quality protein and oil for binding functionality. Flours and other dried formulations can increase the shelf life and versatility of biomass ingredients. **Algama** was granted several patents for meat alternatives, milk substitutes, and egg substitute formulations, as well as water-soluble ingredient extraction.
- **Innovative processes provide flexibility: Mycorena** developed a patent-pending circular co-cultivation process for growing microalgae and fungi. **Universidade de Santa Cruz Do Sol** researchers demonstrated that brewery waste streams can support protein-rich *Euglena* production, thus showcasing sidestream feedstocks for microalgae cultivation.

✦ *Key takeaway*

Microalgae are metabolically flexible compared to other microbes, thriving under phototrophic (light-driven) or heterotrophic (organic carbon-driven) growth conditions and across temperature ranges. These evolutionary adaptations enable manufacturers to leverage microalgae's unique functional properties as ingredients for alternative meats, eggs, dairy, and baking. Microalgal metabolic flexibility also broadens the range of potential low-cost feedstocks, such as carbon dioxide and water-soluble carbohydrates from industrial sidestreams, and positions them as a sustainable source of nutritious ingredients.

Advances in bacterial SCP processes can unlock sustainable protein production

Gas fermentation sequesters abundant, low-cost, greenhouse gases like carbon dioxide, carbon monoxide, and methane into SCP for food, addressing protein demand while benefiting the climate. Advances in 2024 include:

- **Bioreactor innovations:** Designs were improved for commercialized loop bioreactors that enhance gas transfer. In 2024, **Calysta** patented their U-loop bioreactor design, **NovoNutrients** developed a pilot plant bioreactor with a looped cylinder design, and **University of Queensland** researchers evaluated a hollow fiber membrane bioreactor for efficient anaerobic valorization of waste methane.

- **Optimized bioprocesses: Aerbio** and **Solar Foods** patented their high-efficiency continuous production processes with economically promising yields. **NovoNutrients** focused their efficiency gains on enriching minimal, lower-cost media using carbon-fixing microbes.

- **Upcycled gas feedstock valorization: Ghent University** and **VTT** researchers advanced syngas-to-acetate methods, demonstrating cost-effective pathways to produce SCP. **King's College London** researchers, led by GFI Grantee Prof. Miao Guo, identified over 100 strains capable of converting industrial and food waste gases into SCP. Adding to their microbial strain developments, **NovoNutrients** patented a process to generate SCP with a bacterium consortium and gas feedstocks.

- **Expanded product applications: LanzaTech**, in partnership with the U.S. Navy, patented their ingredient process for cheese, fermentation-enabled meats, breads, and smoothies.

- **Anaerobic fermentation as an alternative:** Anaerobic fermentation eliminates supplemental oxygen needs, reducing costs. **Superbrewed Foods** anaerobically generates SCP from corn glucose, building on their portfolio of safe bacterial biomass protein (a first in the U.S.) and *Clostridium tyrobutyricum*.

✦ *Key takeaway*

Captured carbon and upcycled waste could transform from an environmental liability into a resource for sustainable, functional, and versatile food production via gas fermentation. By optimizing feedstocks, bioreactors, and bioprocesses, companies are paving the way for carbon-neutral, or even carbon-negative, protein production–helping to meet the growing demand for meat in a sustainable way.

See GFI's Substack post on bacterial proteins, a microbial valorization of waste feedstocks to SCP review, and CASA-Bio's report, "Creating Value from Waste Carbon for a Circular Bioeconomy."

Precision fermentation ingredients and production

Precision fermentation (PF) harnesses microorganisms to produce specific ingredients for food, including functional dairy, egg, meat proteins, and fats. By achieving strain titer advances, downstream processing improvements, novel end-product formulations, process validation, and intellectual property milestones, developments in 2024 paved the way toward price and taste parity.

Whey-ing dairy protein priorities: high-volume BLG versus high-value lactoferrin

Cooling developments in beta-lactoglobulin as production scales

Beta-lactoglobulin (BLG) is the primary whey protein in dairy products like milk and yogurt, bakery items like breads and cakes, and nutritional supplements, often derived from cow's milk. With high digestibility and functionality, versatile PF-derived BLG has clear channels for demand. Meeting global whey protein demand will require various manufacturers and production methods.

In 2024, players in the space focused on end-product applications, maximizing yield, and scaling production. **Perfect Day** engineered esterase activity in PF microbes to optimize yield while **Vivici** validated demonstration-scale (75 kL) production in Europe and submitted a Generally Recognized As Safe (GRAS) notice to U.S. FDA. With the potential of precision fermentation in creating tailored functional proteins, researchers at **Massey University/Vivici** and **Wageningen University** demonstrated increased BLG food functionality through protein sequence variation and processing interventions, while **ImaginDairy** fused whey and casein to make a multifunctional protein.

Increased interest in high-value whey lactoferrin

Lactoferrin (LF), a multifunctional iron-binding whey protein valued as a nutraceutical in food, continued to garner interest in 2024. Lactoferrin concentrations in milk are very low, which makes extraction from milk costly and PF production economically compelling.

Researchers focused on maximizing lactoferrin bioactivity and titer: **TurtleTree Labs**' LF demonstrated high bioactivity, iron binding, and stability relative to native bovine LF, with a GRAS notice submitted. **Helaina**, developing LF for infant formula and adult nutrition, was granted patents for improved milk protein expression systems in *Komagataella phaffii*. Scientists at **Friesland Campina** used high-throughput screening to increase titer, and **National Chung Hsing University** reported a *K. phaffii* titer of 2.3 g/L for bioactive porcine lactoferrin. However, further titer improvements are necessary (but may be unreported by industry) to meet **Intelligen**'s techno-economic assessment, which models the economic viability of LF production at 10 g/L titer, with PF LF costs up to seven-fold lower than conventional LF ($260/kg versus up to $2000/kg).

> ✦ *Key takeaway*
>
> Advances in BLG and LF titer, yield, and functionality provide further traction for technical progress. The PF sector has focused on whey proteins like BLG for many years due to their functionality and market opportunity, but interest has expanded to high-value, low-volume lactoferrin. For those building infrastructure and pipelines for PF dairy, lactoferrin offers a chance to produce a high-value protein at smaller volumes, while gaining bioprocessing experience and scaling up production. These PF dairy proteins can provide similar functionality in familiar dairy products as their animal-derived counterparts for consumers.

Next-gen cheese: How casein innovations are unlocking cheese formulations

Cheese is a technically challenging product to replicate due to the unique functionality of casein, which forms micelles, the base ingredient for most cheesemaking. These small complexes of casein proteins, calcium, and fats have important roles in curd formation, gelation, and stretchability. Advances in 2024 include:

- **Casein micelle processes advanced:** Researchers from **Wageningen University**, **Eindhoven University of Technology**, **Helmholtz Zentrum Hereon, Ghent University**, **All G Foods**, and **Dairy X** explored factors that influence casein micelle formation, including salts (especially calcium phosphate), temperature, and pH, and how these affect critical performance parameters like gelation.
- **Enhanced casein products:** Groups from **Wageningen University**, **Those Vegan Cowboys**, and **Zero Cow Factory** improved casein functionality by evaluating oil-water interfaces, enhancing stretch, and developing multifunctional casein protein fusions. **Wageningen University** researchers also advanced more efficient downstream processes.
- **Investing in formulation R&D yields desirable end-products while reducing costs:** Major dairy cooperative, **Fonterra**, signaled their interest by patenting alternative cheese formulations using recombinant casein. **New Culture** lowered costs by reducing inclusion rates relative to conventional mozzarella. Their alpha casein production and low-inclusion formulations (9%–15%) patents suggest that reduced protein phosphorylation, typically regarded as a necessary modification to recapitulate, does not necessarily impair functionality in proper formulation.

✦ *Key takeaway*

Advances in understanding calcium interactions, micelle assembly, and interfacial behavior, supported by novel patents for recombinant casein production, can optimize cheese formulation. Progress through 2024 signals the readiness of the industry to tackle remaining bottlenecks, with companies refining downstream processing, lowering inclusion rates, and achieving functionality that rivals or exceeds conventional cheese, bringing us one step closer to animal-free cheese that shares familiar taste, stretch, and melt properties.

Egg protein innovations advance commercial readiness

Egg white proteins (EWPs) are used extensively in baked goods, ice creams, nutritional supplements, and meat alternatives, owing to their comprehensive amino acid composition and versatile functional attributes like gelation. Breakthroughs this year enhanced functionality, titers, and bioprocess:

- **High titer progress in the private sector: EVERY Company** reported ovalbumin titers from 17–30 g/L in *K. phaffii,* and **Onego Bio** reported 120 g/L in *Trichoderma reesei*, representing significant strides over previously published titers in *S. cerevisiae*, *K. phaffii*, and *T. reesei*.
- **Exploring novel EWP functionality**: **Eggmented Reality** identified, using bioinformatics, highly functional egg ovalbumin from pigeon, flycatcher, and hamerkop with enhanced gelation relative to hen egg ovalbumin. Additionally, the **EVERY Company** was granted patents for their highly soluble ovomucoid egg protein production and formulation.
- **Process control innovation:** Developed by **The Protein Brewery**, process control innovation helps reduce bioreactor foaming during EWP production. While foaming is a desirable egg ingredient attribute, it can interfere with bioreactor operation. Companies must develop similar food-grade antifoam strategies to mitigate this issue.

> ✦ *Key takeaway*
>
> Significant developments in PF-derived EWP titers represent commercially viable firsts for scaling PF egg proteins, with up to 60-fold enhancement relative to academic reporting just a year prior. Additionally, alternative variants offer enhanced functionality versus traditional chicken egg proteins, potentially reducing formulation cost-in-use and enabling broader adoption.

Photo credit: Onego Bioi

Meat-enhancing proteins still hold promise to improve taste and texture

While fermentation-derived ingredients like amino acids and yeast extracts are already widely used in food to improve taste, PF proteins like heme, myoglobin, and collagen replicate meat sensory characteristics. Developments in 2024 included:

- **Focusing on improving downstream processing:** To maintain protein integrity, **Impossible Foods** was granted a patent for extracting, in-process formulating, and purifying globin proteins, like heme. GFI also selected three grantees to receive research funding to explore open-access solutions for improving downstream processing approaches for extracting and purifying collagen and heme.
- **Potential cost data gaps identified**: **Intelligen**'s techno-economic assessment for PF collagen, intended for cosmetic/biomedical applications, modeled a $940/kg cost of production, assuming an 18 g/L titer. While these applications require higher purity, these titers and cost profiles are not economically tractable for food and highlight the need for food-relevant cost modeling.
- **Optimizing functionality and cost for food formulations**: This year, GRAS filings represent R&D progress to improve cost and functionality, and may hint at future formulation plans. **Impossible Foods** and **Geltor** submissions have intended inclusion rates at 2% for leghemoglobin (pending; increased from 0.8% in a previous filing) and 95% for dietary collagen protein, respectively.

✦ Key takeaway

By enhancing the taste and color of plant-based meat to align better with consumer expectations, heme protein has been a trailblazing precision fermentation-enabled protein, and continued processing improvements and scaling are needed to reduce costs further. Collagen has growing commercial interest and could provide both structural and functional roles in replicating meat structure and texture. Geltor's GRAS submission for dietary collagen suggests this ingredient may, after years of development, be primed for commercialization as a high-inclusion functional food.

Microbial oil advances offer sustainable and functional alternatives

Microbial oils from yeast and microalgae, particularly those valorizing sidestreams, are sustainable, functional alternatives to traditional animal fats and plant oils for meat and dairy products. Notable developments in 2024 include:

- **Vegetable oil alternatives**: **Zero Acre Farms**' microalgal oils offer reduced reactive aldehydes during frying, lower cooking energy needs, and enhanced emulsion stability. **C16 Biosciences** secured funding to scale their fat-producing yeast strains, targeting microbial palm oil alternatives with higher melting points and via blending strategies.
- **Sustainability advances**: Research focused on utilizing waste feedstocks, including bread waste, valorized syngas, recycled biomass, and cocoa sidestreams, for microbial oil production. Efforts by **Technical University of Munich**, **Taizhou University**, and GFI grant recipient Dr. Naazneen Sofeo aim to reduce reliance on traditional oils.
- **Functional lipids**: Companies are advancing tunable microbial functional lipids to replicate meat and dairy fats. **Melt&Marble** patented triacylglyceride formulations to replicate animal fats, while **Nourish Ingredients** discovered microbial phospholipids that mimic meat fats with fewer unhealthy saturated fats. For dairy fat alternatives, **Cultivated Biosciences** developed lipid oleosomes, which improve fat delivery and functionality, and **Nourish Ingredients** partnered with **Fonterra** to expand their microbial lipid product applications.

> ✦ *Key takeaway*
>
> While commodity plant- and vegetable-oil cost parity may be a long-term milestone, an immediate focus on low-inclusion, high-taste, and nutritional lipids can improve meat and dairy formulations' taste, texture, and nutrition. To achieve widespread adoption, challenges in production efficiency and cost reduction must be addressed.

Positioning fermentation as an essential component of a sustainable food system

In 2024, fermentation continued to demonstrate potential for climate, nutrition, and food safety.

Climate

Environmental benefits were corroborated, with promising life cycle assessments from **MushFoods** and **NOSH** showing 50% to 90% lower footprints than conventional beef, and **Bon Vivant**'s PF BLG demonstrating improved sustainability. **Meati's** award-winning facility illustrates sustainable manufacturing practices. However, areas of optimization remain, especially in carbon feedstocks. Groups explored sustainable alternatives from corn dextrose or acetate, reaping bonus nutritional benefits.

Nutrition

In nutrition research, biomass and SCP can positively affect gut microbiota, reduce serum cholesterol, be highly digestible, and have low fat. Nutritional properties can be tuned through feedstock selection, but end product processing, including heating to reduce RNA and extrusion to texturize, may offset some benefits and reduce protein quality or digestibility, highlighting the need for further development.

Food safety

To maintain food safety, new databases and tools can accelerate the search for allergen-free novel microbes, especially for milk proteins. Researchers determined that protein purity and homology are important considerations to avoid immune responses.

✦ Key takeaway

Fermentation products must be nutritious and safe for consumers and continue to demonstrate their vital role in a sustainable food systems transformation. In 2024, findings highlighted high digestibility and healthy fat profiles, and the need to preserve benefits through careful processing. Researchers advanced our understanding of mitigating allergenicity and risks like mycotoxins, by developing better models and predictive tools, which are crucial for targets that mimic allergenic animal proteins and as purity standards are refined. Environmental advantages of fermentation were reaffirmed, though areas for further focus include alternative feedstock development and improving data availability, especially for precision fermentation.

Check out reviews of SCP and mycoprotein environmental drivers, recent reviews on biomass nutrition, as well as GFI's 2024 report on omega-3s, and a dairy protein safety review.

Global innovation landscape: Scientific ecosystem grows while patent traffic tempers

Scientific ecosystem growth gains healthy momentum

Research centers and manufacturing facilities launched in 2024 will generate translational, scalable innovation.

Research centers

Three new Centers of Excellence in Alternative Protein, funded by the Bezos Earth Fund, were founded at Imperial College London, the National University of Singapore, and North Carolina State University. Meanwhile, NAPIC and SUSFERM launched fermentation-focused research centers.

New pilot capabilities

From Australia's FaBA to the iFAB in the U.S., new facilities were planned, while **MISTA** commissioned a high- and low-moisture extruder for piloting end products. In Brazil, GFI recently mapped 13 institutions with fermentation infrastructure and >25 L bioreactors that are being used in the scale up of alternative proteins.

Expanding facilities

BBEU commissioned 75 m^3 demonstration-scale bioreactors, while **Danone** partnered with **Michelin** and **DMC Biotechnologies** to develop an innovation campus with a 10 m^3 bioreactor and downstream processing equipment.

✦ Key takeaway

Until recently, R&D was dominated by the private sector. New research centers will progress foundational research in the public sector with an eye toward commercialization. Encouragingly, new products will have access to more pilot facility spaces as they move to the critical next step of scaling. Public investment lowers the production barriers by supporting capital investments and construction, and importantly, investments made through partnerships can accelerate infrastructure.

Check out GFI Europe's funding and publications R&D landscape reports.

Patent activity tempers after record highs

Progress in reported intellectual property, while often a lagging indicator of funding return, can be a leading indicator of product development and pending market entry. Global fermentation alternative protein patents have surged over 6500% in 10 years to over 2,400 unique filings and 1,000 patent families, with most in biomass fermentation and a jump in precision fermentation.

Photo credit: Pacifico Biolabs

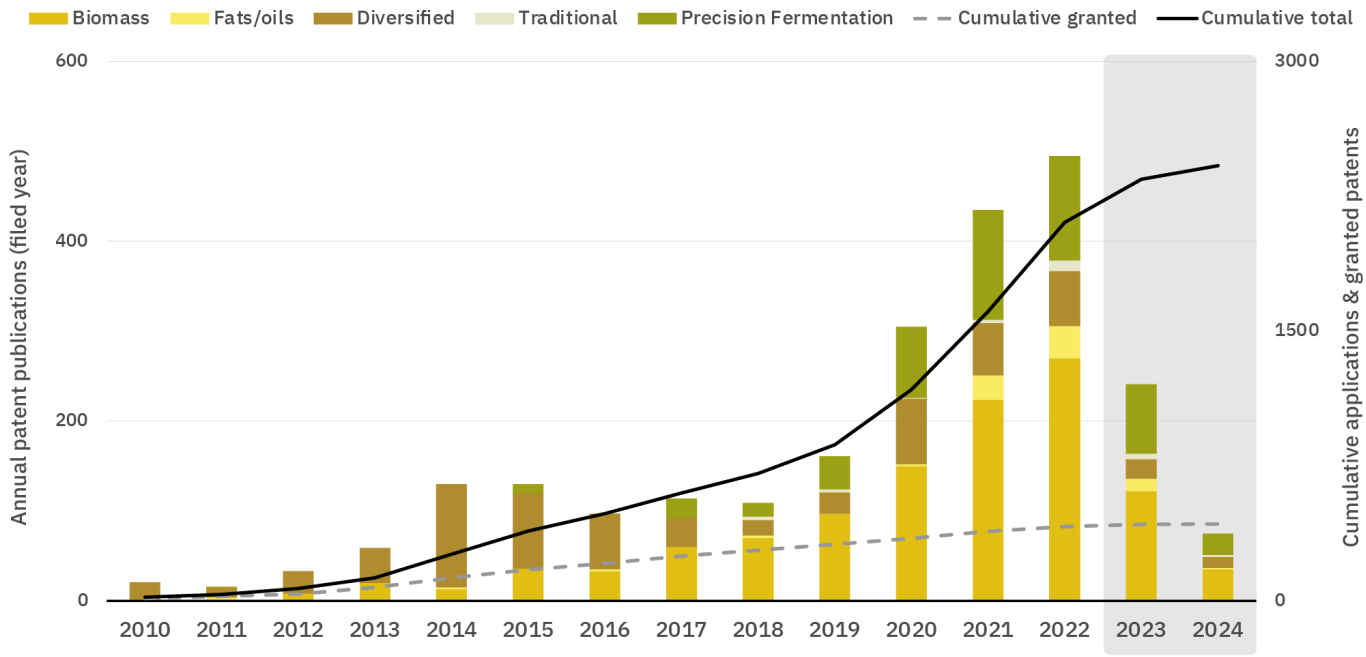
However, patent activity has potentially slowed since 2022, coinciding with a global funding downturn, though this could be explained by a potential 18-month publication lag after filing. Despite the publication lag and potential filing slowdown, unique patent family and assignee applications hit an all-time high in 2023 with 191 family filings across 83 companies and institutions, highlighting an active pool of fermentation innovators.

Globally, the United States remains the leading filing jurisdiction among these applicants, with more than 400 since 2020, followed by Europe, Australia, Canada, Israel, South Korea, and China. In 2023 and 2024, activity increased in Europe, Israel, and the United Kingdom, suggesting innovation hotspots or emerging targeted operating markets.

✦ *Key takeaway*

Innovation continues despite funding challenges, especially in biomass fermentation. Further, as funding has decreased, many companies may carefully consider whether, how, and where to protect their intellectual property and commercialization plans. Importantly, each new publication and patent adds to the collective foundational knowledge needed for fermentation price and taste parity, the achievement of which is essential for the industry's success.

Figure 13. Annual patent filing and cumulative patent activity
by filed year and company pillar focus



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Jurisdictions	10	7	15	15	24	25	26	26	19	25	26	24	26	22	10
Assignees	3	5	5	7	9	10	12	18	26	25	37	67	81	83	41
Unique patent families	10	6	10	29	46	46	35	47	47	57	94	169	178	191	68

Annual and cumulative fermentation patent filings from 2010 to 2024 by application filed year and technology focus, as well as annual patent family publications. Applications represent total unique patent filings across jurisdictions.

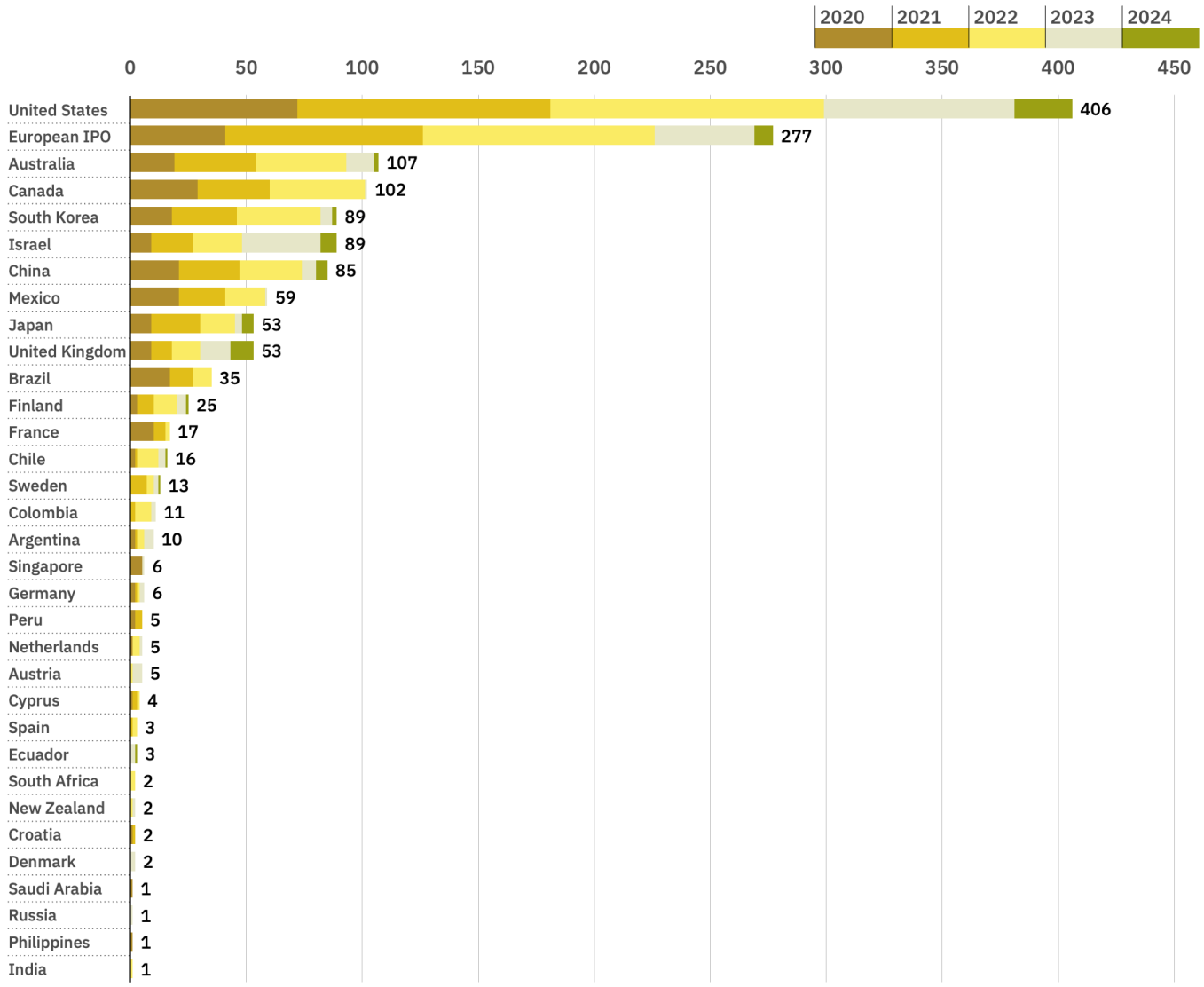
Gray area: Incomplete data for 2023 and 2024 shown in gray area. Applications filed in 2023 and 2024 could have delayed publication and not accurately inform total patents filed in those years, since patent filing publications can be delayed up to 18 months after filing.

Data sourced from Dimensions, an interlinked research information system powered by Digital Science.

Expanding on our 2023 patent landscape, this patent landscape focused on fermentation companies in the GFI company database, using curated assignee legal filing name, as well as keyword patent TAC searches, and TAC exclusions. Duplicate patents were removed by family ID and jurisdiction by first filing year, and the remaining patents were manually screened for relevance to food and enabling technologies. Assignees were updated and clustered by the most relevant company/assignee name. You can learn more about many of these companies in the GFI company database. Are we missing something? Let us know by filling out our company database edits form or contact us at corporate@gfi.org.

Figure 14. Fermentation patent jurisdictions

by filed year and application origination jurisdiction



Fermentation intellectual patent office (IPO) filing jurisdictions for patents filed between 2021–2024. Jurisdictions are listed as the application origination jurisdiction.

Applications filed in 2023 and 2024 could have delayed publication and not accurately inform total patents filed in those years, since patent filing publications can be delayed up to 18 months after filing.

Data sourced from Dimensions, an interlinked research information system provided by Digital Science.

Figure 15. Assignee patent totals
2022-24

Filed Granted

Traditional

1	0	Agro Ludens	2	0	Mediterranean Food Lab	2	1	Protein of Tomorrow	5	1	Planetarians
2	0	MTR Foods	2	0	Meeat Foodtech Oy	5	0	Eight Day Foods			

Fats/Oils

1	1	Clean Food Group	1	4	Melt & Marble	5	0	Technical University Munich	8	0	Zero Acre Farms
1	0	Cultivated Biosciences	2	1	NoPalm Ingredients	8	0	C16 Biosciences	25	0	Nourish Ingredients
1	0	Jiangnan University									

Diversified

1	23	Corbion	1	0	Unilever	5	0	Hanwha Solutions Corp	8	2	Shiru
1	0	Kikkoman Corp	3	1	CJ CheilJedang Co.	6	3	Checkerspot	21	10	MycoTechnology
1	0	Ummino	3	1	Jiangzi Fushine Biotech	6	0	The Cultivated B	39	24	Impossible Foods

Precision fermentation

0	1	Melt & Marble	1	0	VTT	5	0	Luyef Biotech	11	0	Remilk
1	0	Change Foods	2	0	All G Foods	5	2	Paleo	12	2	Amai Proteins
1	0	Daisy Lab	2	0	Better Dairy	8	4	Perfect Day	14	0	Formo
1	0	Eggmented Reality	3	0	Nextferm Tech	9	8	Geltor	18	0	Motif FoodWorks
1	0	Ingrediome	3	0	Zero Cow Factory	9	2	Helaina	70	9	The EVERY Co.
1	0	Phyx44 Labs	4	0	Changing Biotech	10	1	New Culture			
1	0	Protein Brewery	5	0	ImaginDairy	10	0	Standing Ovation			

Biomass

0	1	Beijing Tech and Business University	1	0	Shaanxi University of Science and Technology	2	0	Sophie's Bionutrients	7	0	EniferBio
0	1	Mitsubishi Corp Life Sciences Ltd	1	0	Shinsegae Food Inc	2	0	ProteinDistillery	7	0	Equii (Cella Farms)
0	2	Seafood Reboot SAS	1	0	SimpliiGood	2	0	Walding Foods	8	0	Arkeon Biotechnologies
0	1	Smallfood, Inc.	1	1	South China Agricultural University	2	0	Zheijiang University ZJU	8	0	Eternal Mycofood
1	0	Adamo Foods	1	0	Unibio	3	1	Enough	8	2	Koralo
1	0	Angel Yeast Co	1	0	Universidad De Valladolid	3	6	Triton Algae Innovations	10	8	Algama
1	0	Batel Meat Ltd	1	1	Wild Earth	4	0	Alver World SA	10	1	Meati
1	0	Chuck Foods	1	0	Zheijiang University of Technology ZJUT	4	0	Nosh.bio	10	0	MicroHarvest
1	0	Daesang Corp	2	2	Brevel	4	7	NovoNutrients	10	0	Yeap
1	2	Deep Branch	2	0	Farmless	4	1	Revyve	15	1	Prime Roots
1	0	Fender Group	2	0	Hyfe Foods	4	0	YeastUp	20	9	Marlow Foods
1	0	Fermify	2	0	Innomy Biotech	5	0	CIRCE	21	1	Air Protein
1	0	Guangzhou Bioform Biotech Co ltd; S China Agricultural Uni.	2	0	Kaist	5	0	Houdek	21	1	Ecovative (MyForest Foods)
1	0	IFF	2	0	Kontor N GmbH	5	4	Protein Brewery	21	0	Mycorena
1	1	Kynda Biotech	2	0	Microo Food Ingredients SL	6	1	Aqua Cultured Foods	25	0	Infinite Roots
1	0	Nanjing Normal University	2	0	Millow	6	1	Better Meat Company	30	6	Superbrewed Foods
1	0	Nourish Ingredients	2	0	MycoWorks	6	0	Sun Food Co Ltd	35	16	Nature's Fynd
1	0	Ohly GMBH	2	0	Natural Resources Institute Finland	7	7	Calysta	54	4	Solar Foods
1	0	Planetary SA									

Assignee patent filings and granted patents from 2022–2024. Applications filed in 2023 and 2024 could have delayed publication and not accurately inform total patents filed in those years, since patent filing publications can be delayed up to 18 months after filing. Data sourced from Dimensions, an interlinked research information system provided by Digital Science.

Government and regulation

Overview

As companies develop innovative fermentation methods, governments are showing an increased interest in supporting fermentation technology through economic investments and regulatory advancements. In 2024, public support for fermentation technology continued across the Asia-Pacific region, Europe, and the United States. Several companies around the world were also able to bring their novel fermentation-derived ingredients to market in 2024, after successfully navigating the regulatory pathways for these products.

Global public investment

Americas

Public support for fermentation surged in the United States in 2024 with a wave of support from a variety of federal agencies and state governments. Led by a $51 million investment in precision fermentation capacity in Illinois, the United States government eventually funded nearly 25 research projects or startups advancing fermentation technology for defense, economic development, agricultural benefits, or nutrition enhancement. Fermentation-derived protein technologies sit squarely in the center of the emergent bioeconomy, as the field's science, equipment, and infrastructure overlap significantly with those needed for pharmaceuticals, biofuels, bio-based materials, and more. While Brazil and Canada continued to support fermentation at low, consistent levels, the nearly $125 million the United States put toward fermentation indicates a sea change in policy perception of this versatile, powerful technology. While new fermentation technologies offer a wide range of benefits, further public investment is needed to reach important scale and sensory benchmarks.

- **iFAB Tech Hub:** In July 2024, the Department of Commerce's Economic Development Administration awarded a $51 million grant to the University of Illinois Urbana-Champaign to found the United States' first lab-to-product innovation hub for precision fermentation.
- **Research and business grants:** At least 20 announced projects between the National Science Foundation, the Department of Defense, the Department of Energy, and the Department of Commerce advanced alternative proteins to secure U.S. leadership in biomanufacturing, defense logistics, and future industries.
- **Rallying public and private investment:** In the wake of the iFAB announcement at the University of Illinois at Urbana-Champaign, the state of Illinois announced significant public and private follow-on investment to further lift up Illinois as a leader in biotechnology.

✦ Key takeaway

U.S. action in 2024 proves beyond a shadow of a doubt that the United States can lead in biotechnology and food science. Powerful, smart, and targeted government support united scientists, farmers, and manufacturers behind the iFAB Tech Hub in Illinois, which will continue to create jobs and economic value for the region as a whole. Carried forward, a U.S. biotechnology program can accelerate these benefits while being cost-effective and targeted.

Asia Pacific

Public support for fermentation grew significantly across APAC in 2024. Leading this growth are the governments of China and India, which both announced national plans to develop food biomanufacturing through government-supported research hubs and bioeconomy programs. While these broad biotechnology plans encompass technologies and priorities beyond the scope of alternative proteins, they include fermentation technologies prominently. Meanwhile, Japan, Singapore, and South Korea also funded public research to advance fermentation science and improve the consumer experience. Australia supported growth in domestic fermentation capacity through grants from both the federal government and the state of Queensland for a contract manufacturing plant specializing in precision fermentation, which will reduce the bottleneck in capacity for startups to test and scale new products.

- **India**: The world's most populous country allocated INR 9197 Crore ($1.1 billion) through 2026 under the Biotechnology Research Innovation and Entrepreneurship Development (Bio-RIDE) scheme, a component of the BioE3 policy. The Bio-RIDE scheme highlights alternative proteins as a key sector in food sciences and biotechnology to help establish India as a global biomanufacturing hub and nurture the circular bioeconomy.
- **South Korea:** The Ministry of Agriculture, Food, and Rural Affairs included six alternative protein research topics (three in plant-based, two in cultivated meat, and one in fermentation) in their multiyear, high-added-value food technology development program.
- **Japan**: Japan launched several research projects on fermentation and awarded business development funding for a fermentation startup.
- **Singapore:** Singapore Food Agency opened a second Future Foods call for proposals, this time focusing on plant-based and fermentation-derived alternative proteins and research to "increase the consumer acceptance of future foods by improving their flavour, texture and nutritional properties."
- **Australia:** Australian policymakers supported the development of the precision fermentation industry, with both the federal government and the State of Queensland supporting Australian startup **Cauldron Ferm** in constructing the first large-scale end-to-end contract manufacturer for precision fermentation-derived products in the Asia Pacific region.

Europe

European countries made major investments in fermentation in 2024, with large funding packages from the European Union, Finland, France, the United Kingdom, and more fueling the development of fermentation capacity across the region. These funding packages help to build an innovation center in the UK, support foundational research through the EU's biotechnology research program, and promote the development of fermentation capacity at scale in France.

This funding reflects a global surge of confidence in fermentation as a tool to address regional and global challenges from food security to economic development.

- **European Union:** After earmarking €50 million ($54.9 million) to advance commercialization of food from precision fermentation and algae in 2024, the EU announced that in 2025 it will support "Biotechnology driven low emission food and feed production systems" with additional funding. Within that scope is "precision fermentation for the sustainable production of food and feed ingredients traditionally derived from animal or plant sources."

- **Finland:** Business Finland—a world leader in supporting the advancement of food technology—announced €10 million ($10.8 million) in funding to two Finnish alternative protein projects.

- **France:** Precision fermentation startup Standing Ovation received €3 million ($3.3 million) from the French government and Bpifrance to scale nonanimal caseins for novel dairy products.

- **Sweden**: Swedish institution RISE Processum successfully bid to coordinate two Horizon Europe projects focused on fermentation in 2024, totaling almost €10 million ($11 million). PLANTOMYC will investigate fungal mycelia for plant-based meats, while DELICIOUS will focus on producing flavor and texture for plant-based foods via fermentation.

- **United Kingdom:** In early 2024, Imperial College London received £12.6 million ($16 million) to establish the BBSRC-funded Microbial Food Hub. Focused on fermentation, the center will conduct critical R&D as part of the UK government's commitment to engineering biology. The Microbial Food Hub is led by Dr. Rodrigo Ledesma Amaro, who is also the director of the new Bezos Centre for Sustainable Proteins at Imperial.

Israel

The government of Israel continued to demonstrate leadership in supporting alternative proteins, including fermentation, in 2024, sustaining high levels of public investment for innovation and commercialization and rallying international efforts to highlight the benefits of food technologies. Joint funding calls with both the United Kingdom and France specifically mentioned alternative proteins as "transformative" and "innovative" technologies," while the Israel Innovation Authority continued to provide supportive grants for both research and industrial development.

- **Accelerating research and commercialization**: In 2024, the Israel Innovation Authority awarded around $9.7 million in R&D grants for alternative protein startups and researchers.

- **Developing international collaborations**: Israel awarded $370,900 for alternative protein research through a UK research partnership and $90,000 through a partnership with France.

Regulation by country and region

Most governments have well-established regulatory systems that allow the use of microbial fermentation in the food system. In 2024, companies and governments worked together to bring innovative fermentation-derived products to market.

Australia/New Zealand

Food production and sales in Australia and New Zealand are jointly regulated by Food Standards Australia New Zealand (FSANZ). FSANZ made no public moves regarding fermentation-derived foods in 2024.

- In May 2024, New Zealand's **Daisy Lab**, a precision fermentation biotech company, received approval from the New Zealand Environmental Protection Authority (EPA) for their application to expand their dairy protein production platform to 5,000 liters. The application was made under the New Zealand EPA's rapid assessment pathway, which provides a decision to the applicant within 10 working days.
- To receive this type of approval, applicants must demonstrate their stringent safety standards and that their facility will be inspected. This regulatory approval will enable the construction of a pilot facility, marking a significant step forward in scaling and marketing this technology in New Zealand, the largest global dairy exporter.

Canada

Canada approved fermentation-derived animal-free milk for the first time in January 2024, when Health Canada issued a "Letter of No Objection" indicating that it does not have food safety concerns about the use and sale of **Remilk**'s animal-free milk protein.

- For Remilk to obtain this approval, Health Canada conducted a comprehensive assessment of the animal-free protein under the Guidelines for the Safety Assessment of Novel Foods, which are based on internationally accepted principles for establishing the safety of foods with novel traits.
- In their "Letter of No Objection," Health Canada suggested that Remilk include the name of the source material on product labels and clearly communicate the allergenic risk of these products to consumers with dairy allergies. The labeling requirements for this protein are governed by the Safe Food for Canadians Regulations and the Canadian Food and Drug Regulations. The Canadian Food Inspection Agency will ultimately be tasked with enforcing labeling requirements.
- Remilk intends to sell their protein directly to food manufacturers as a nonanimal source ingredient for use in nutrition bars and beverages, cheese, ice cream, yogurt, and plant-based drinks, at which point the products may be subject to additional product-specific regulatory requirements.

European Union (EU)

The European Food Safety Authority (EFSA) accepted an application from the first Nordic company (**Enifer**, a Finnish biotech startup) to seek regulatory approval for a mycoprotein ingredient in late 2024. The ingredient will be evaluated under the EU's Novel Food Regulations, which state that any food not widely consumed before May 1997 requires a thorough safety assessment before it can be approved in the European market.

- EFSA's safety assessment is rigorous and may take years. Once approved, the mycoprotein ingredient can be incorporated into alternative protein and dairy products as an environmentally responsible food source that aligns with the EU's goals for a more sustainable food system.

India

Throughout 2024, the Indian government took actions to advance regulatory pathways and policies for all types of alternative proteins, including fermentation-derived proteins.

- In April 2024, the Department of Biotechnology (DBT) and the Biotechnology Industry Research Assistance Council (BIRAC) organized a closed-door Regulatory Conclave on Smart Protein. The DBT-BIRAC Conclave was a first-of-its-kind dialogue on the regulatory path-to-market for smart protein products—including fermentation-derived meat—convened by a government body in India. It brought together key stakeholders across government (including the apex food regulatory body in India, the Food Safety and Standards Authority of India, (FSSAI) and the Ministry of Food Processing Industries), experts from science and academia, Indian and international companies, industry associations, and the international food standards body, Codex Alimentarius. Their collective expertise provided a comprehensive overview of the challenges and opportunities in the sector, emphasizing that with the right regulatory interventions, India could emerge as a global smart protein leader.
- In July 2024, **Nature's Fynd**'s biomass fermentation-derived Fy Protein (Nutritional Fungi Protein derived from Fusarium str. flavolapis) received regulatory approval under the novel foods regulatory framework of the FSSAI.
- In August 2024, the Indian Union Cabinet approved the BioE3 policy (Biotechnology for Economy, Environment, and Employment Policy for Fostering High-Performance Biomanufacturing) with alternative proteins (including fermentation-derived proteins) as one of six key thematic sectors. The policy provides a framework for Indian institutions, universities, startups, and industries to engage and propel innovation across six sectors, including "functional foods and smart proteins." This policy specifically references harmonizing regulatory reforms with global standards to facilitate an environment that is conducive to producing and commercializing novel food products, while also considering biosafety and security. The BioE3 policy has the power to act as a catalyst for fermentation-derived protein industry growth in India.

United States

There are two regulatory pathways that companies can follow to sell novel fermentation-derived foods and ingredients in the United States. The first pathway requires companies to submit a food additive petition (or color additive petition for ingredients that impart color to the food purchased by the consumer) to the U.S. Food and Drug Administration (FDA). This is a lengthy process that involves a consultation with FDA and the submission of a petition requesting that FDA issue a regulation that would allow specific uses of the ingredient or additive in question.

The second pathway is to achieve GRAS status, which can include submitting a GRAS notice to FDA when an ingredient or additive is already "Generally Recognized As Safe" among qualified experts under its conditions of intended use. Companies can bring their products to market as soon as they have affirmed GRAS status, but it is best practice to wait until FDA has issued a "no questions" letter in response to the GRAS notification, indicating the agency does not question the safety conclusion for the product in question.

Fermentation companies typically elect to take the GRAS pathway, as demonstrated by the numerous "no questions" letters sought from or issued by FDA in 2024:

- In January 2024, FDA issued a "no questions" letter to the Israeli alternative dairy company **ImaginDairy** for its animal-free milk proteins.
- In February 2024, U.S.-based fermentation-enabled dairy startup **New Culture** announced that its animal-free, precision fermentation-derived casein is GRAS. New Culture is now seeking a "no questions" letter from FDA.
- Also in February 2024, Dutch fermentation-enabled dairy company **Vivici** obtained self-affirmed GRAS status for its animal-free precision fermentation-derived whey protein. Vivici is now seeking a "no questions" letter from FDA.
- In March 2024, FDA issued a "no questions" letter to **Oobli**, a U.S.-based protein ingredient manufacturer, regarding the GRAS status of their sweet-tasting protein made with precision fermentation.
- Also in March 2024, Dutch ingredients company **The Protein Brewery** announced GRAS status to import, manufacture, and sell their fermentation-enabled protein ingredient, Fermotein, in the United States. That same month, the Protein Brewery received approval from the Singapore Food Agency to import, manufacture, and sell their ingredient in Singapore. The Protein Brewery has not yet received a "no questions" letter from FDA.
- In July 2024, FDA issued a "no questions" letter to U.S.-based biomass fermentation-derived meat and seafood company **The Better Meat Co.** regarding the GRAS status of their Rhiza mycoprotein.

Although the GRAS pathway to market is quicker than submitting a food additive petition, GRAS still requires manufacturers to commission an intensive expert scientific review. By submitting evidence of this review to FDA and receiving a "no questions" letter, companies can safely bring products to market with the knowledge that FDA has reviewed their determination.

✦ *Key takeaway*

Several governments are taking affirmative steps to advance the markets for these products by approving the expansion of production platforms (New Zealand), granting first-time ingredient approvals (Canada, China, the EU), and incorporating these products into forward-looking agricultural strategies (India). As the global demand for protein continues to increase, we are likely to see greater market interest in innovative meat and dairy products created by combining traditional fermentation processes with biotechnology.

Outlook

Overview

The fermentation sector has achieved significant progress over the past decade, but the industry remains in its early stages. Many fermentation-enabled products are only beginning to appear on grocery store shelves and restaurant menus, meaning these products currently represent only a tiny fraction of the global meat, egg, and dairy markets.

The fermentation sector further positioned itself as a viable solution to meet the demand for sustainable and secure food sources in 2024. Elevated funding totals, increased partnership and product activity with major CPG brands, and expanded distribution provided windows into the growing fermentation ecosystem.

Public investment in fermentation—public funding that yields dividends in job creation, food security, and economic growth—reached new highs in 2024 as governments around the world supported research and commercialization, and private investments in fermentation companies increased from 2023 levels.

Several companies reported significant distribution increases, and partnerships with diversified meat, dairy, and CPG companies accelerated. Additionally, multiple fermentation facilities, innovation hubs, and alternative protein centers of excellence opened in 2024, setting the stage for future investments and advancements in alternative proteins. These developments propelled the sector forward in 2024 and laid the groundwork for future progress.

Like the early days of other transformative innovations, fermentation still faces challenges. The fermentation sector remains largely pre-commercial, and the subdued venture funding environment is a headwind for companies looking to scale. Consumer acceptance of each fermentation approach is not yet fully understood, and companies still need to uncover the most effective ways to communicate the benefits of their products to consumers. Those factors, paired with the technical and cost hurdles inherent to any nascent sector, present runway challenges for some fermentation companies—underscoring the need for multipronged financing strategies from public, private, and philanthropic sources.

As the fermentation landscape evolved in 2024, consumers' appetites for meat continued to grow. The Food and Agriculture Organization of the United Nations expects meat consumption worldwide to rise by at least 50 percent by 2050 (from 2012 levels). Multiple strategies will be needed to meet the growing global demand for meat while staying within planetary boundaries. Given sufficient funding and regulatory support, fermentation-enabled alternative proteins can help provide consumers with food that reduces environmental impacts, lowers public health risks, and increases food security.

So, what does the future hold for the fermentation industry? The remainder of this section will explore the category's outlook in 2025 and beyond.

The year ahead

Fermentation enables the production of ingredients and end products with unique functional, environmental, and nutritional benefits. At scale, fermentation-enabled foods could unlock a more secure and less resource-intensive protein supply. In 2024, significant progress was achieved in increasing manufacturing capacity, expanding distribution, and securing government and private sector support. Strategic openings in the conventional protein markets and a changing financing environment also shaped the sector in 2024. All of these trends are likely to continue in the year ahead.

Additional product launches spanning production platforms, product types, and regions are expected in 2025. High-profile partnerships with diversified companies increase the likelihood of expanded distribution, and ongoing supply and disease pressures in the global egg and U.S. beef and dairy markets present additional partnership opportunities for companies looking to diversify and reduce risks within their supply chains. The increased scale resulting from expanded distribution, product launches, and large-scale partnerships could improve production efficiency and lower costs in the years ahead.

The financing environment for fermentation will also continue to evolve in 2025 as several companies scale their operations. It is increasingly clear that private funding alone will be insufficient to fully fund many fermentation facilities. In addition to exploring contract manufacturing and retrofitting opportunities, companies need to develop creative and diverse funding strategies to access growth financing. While venture capital will remain an important component of the sector, a combination of public, private, and philanthropic funding sources will be necessary to support industry growth.

As companies learn to navigate this new financing landscape, those unable to access funding may look to downsize, consolidate with other companies, or close entirely. It will take time to identify the most viable financing paths, so some industry consolidation may occur in 2025.

Despite potential consolidation, expanded distribution and high-profile partnerships with large companies mean fermentation-enabled proteins are increasingly available to consumers in stores and restaurants around the world, and the number of products on the market is likely to continue growing in 2025.

Fermentation-derived proteins and other alternative proteins offer a powerful way to diversify a country's food supply, enhancing its resilience to challenges like bird flu outbreaks, extreme weather, or supply chain disruptions. Produced using innovative methods, these foods can be scaled locally and adapted to a variety of environments, adding flexibility and resilience to our food system.

For example, firms impacted by the high prices and limited availability of eggs could consider incorporating fermentation-enabled eggs or egg replacements into their products, especially in cases where conventional eggs fill a functional need rather than enhance a product's value proposition. Some companies looked to diversify their egg ingredient supply in 2024. For example, the **Vegetarian Butcher**, a subsidiary of Unilever, partnered with U.S.-based precision fermentation ingredient producer **The EVERY Company** to add EVERY's EggWhite to its plant-based meat range.

Alternative proteins mitigate risks in critical supply chains by providing additional sources of key inputs, encouraging cost competition, and promoting long-term input cost stability. By incorporating alternative proteins, we ensure that our food supply can continue to meet demand even when unexpected challenges arise.

Alternative proteins can help mitigate avian flu and other market risks

The rapid spread of highly pathogenic avian influenza globally in 2024 decimated flocks of egg-laying hens, causing egg prices to soar and demonstrating how quickly animal diseases can destabilize the food supply.

Long-term outlook

The fermentation industry still has a long road to parity with conventional meat when it comes to price, taste, and convenience. Companies need to increase scale, lower costs, and communicate the value of their products and production methods to consumers.

Progress occurred on all these fronts in 2024. If fermentation companies can continue to navigate this landscape, an immense opportunity remains. As meat demand grows, so do concerns around conventional meat's long-term supply stability, public health implications, and environmental impacts.

With continued investment, innovation, and collaboration, fermentation-enabled proteins have the potential to provide consumers with the products they love while increasing food security, promoting biodiversity, and protecting public and planetary health.

External projections

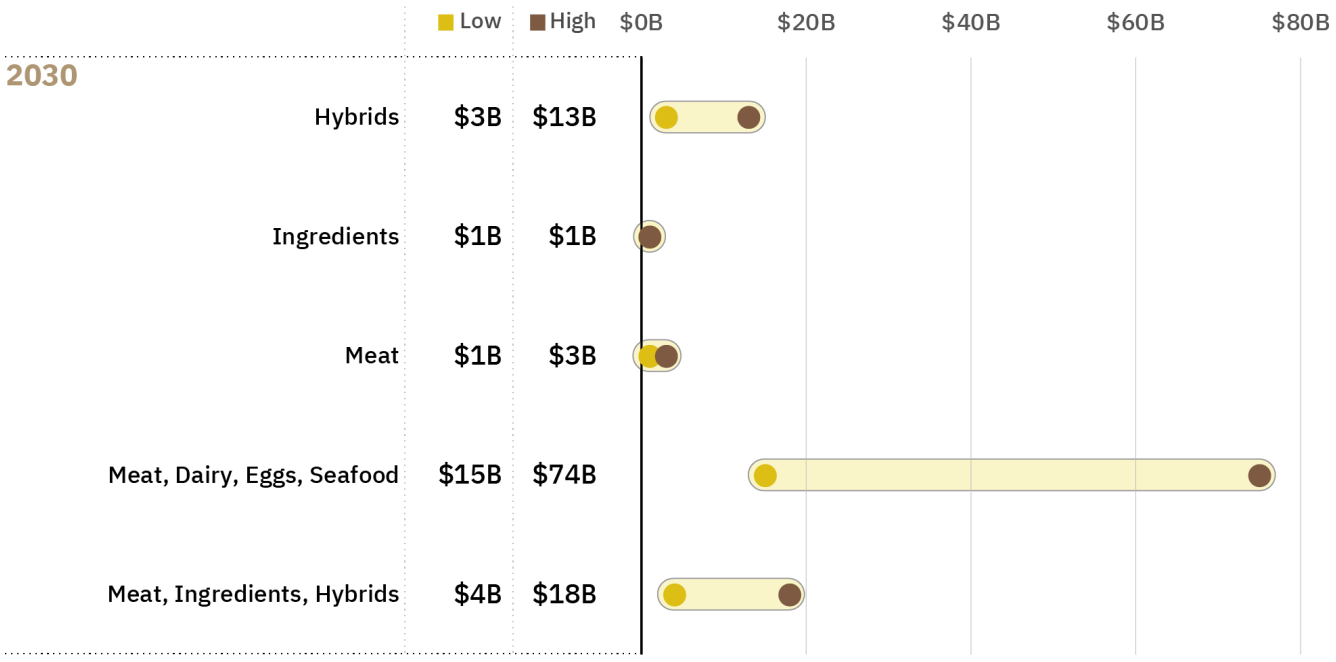
External forecasts of the 2030 fermentation-enabled meat, seafood, eggs, and dairy markets range from ambitious estimates of $15 billion to $74 billion. Those totals represent significant increases from today's market size, which is currently capable of producing 0.4–2.8 MMT (million metric tons) of fermentation-enabled alternative protein products annually.

Meeting even the low-end estimate requires notable advancements in production efficiency, costs, and capacity. Fit-for-purpose contract manufacturing infrastructure would need to scale quickly, and several fermentation facilities from the beer, wine, and biofuel industries would need to be retrofitted for alternative protein production.

Delivering on fermentation-enabled products' potential to meet growing global meat, dairy, and egg demand necessitates public and private investments many times higher than today's norms. Such increases are justified by fermentation's return potential, contribution to supply chain resilience, and land and resource use benefits.

If governments and investors worldwide are committed to achieving better outcomes for citizens and consumers, they should boost investment and strengthen support to position the fermentation sector for long-term success.

Figure 16. Forecasts for global fermentation industry market size from Bryan, Garnier & Co



Source: Bryan, Garnier & Co (2023)

Conclusion

The fermentation-derived protein industry is best understood as a story still unfolding. It is a story of scientific progress amid challenges and headwinds. Of governments investing in protein innovation as part of their food security, bioeconomy, and public health goals. Of a big, bold idea turning its next page, moving ever closer to diversifying how meat is made.

A few reflections on shared values and motivations, as we lean into the critical years ahead together:

Diversifying protein provides more and better choices for consumers, not fewer.

Consumers deserve better food choices and the freedom to make them. Fermentation-enabled proteins can offer meat-eaters a delicious, affordable way to diversify their diets that comes with a side of serious benefits: health and nutrition gains and a lighter environmental footprint, to name just a few. Bringing these proteins to market gives consumers greater choice, enabling them to enjoy their favorite foods made in increasingly sustainable ways.

Diversifying protein can protect our lands, waters, and wildlife.

Growing demand for meat and seafood is placing even greater pressure on farmers and fishers to produce more, at the same time as calls for halting deforestation and overfishing grow louder around the world. Fermentation-enabled proteins are land- and water-efficient, producing more food with fewer resources.

Diversifying protein can build healthy communities by reducing risks to public health and contributing to a more secure, resilient food supply.

Global threats like avian flu and other potential pandemics leave many people concerned about their health, safety, and ability to feed their families. Given the growing global demand for meat, a large-scale shift toward alternative proteins, including fermentation-enabled foods, will be central to mitigating the risk of antimicrobial resistance and future pandemics while feeding a growing population.

To be sure, multiple interventions will be needed to transform food systems at the pace and scale needed to feed a growing world. By their nature, not all will be equal in terms of impact. It's the interventions that address root-causes and realities that can create genuinely transformative new futures. As the primary food and agriculture innovation that can scale similarly to renewable energy, alternative proteins are a root-cause solution that, with the right levels of support, can help meet growing global demand for meat.

To all those in this work already, thank you for channeling your time and talents to this extraordinary, still-unfolding story. You are helping to write the next chapter of a far more sustainable, secure, and just food system that present and future generations deserve.

About GFI

The Good Food Institute is a nonprofit think tank working to make the global food system better for the planet, people, and animals. Alongside scientists, businesses, and policymakers, GFI's teams focus on making plant-based, fermentation-enabled, and cultivated meat delicious, affordable, and accessible. Powered by philanthropy, GFI is an international network of organizations advancing alternative proteins as an essential solution needed to meet the world's climate, global health, food security, and biodiversity goals.

All of GFI's work is made possible by gifts and grants from our global community of donors. If you are interested in learning more about giving to GFI, contact philanthropy@gfi.org. To learn more, please visit www.gfi.org.

We focus on three programmatic priorities:

Cultivating a strong scientific ecosystem

We map out the most neglected areas that will allow alternative proteins to compete on taste, price, and nutrition. We meet these challenges by developing open-access research and resources, educating and connecting the next generation of scientists and entrepreneurs, and funding open-access research across the sector.

Influencing policy and securing public investment

We ensure that alternative proteins are a part of the policy discussion around global health, future-resilient jobs and bioeconomies, and food security. In every region where we have a presence, we advocate for public investment for open-access research on alternative proteins, and increasingly, we work to advocate for government resources to support scale- up and commercialization. We also advocate for level regulatory frameworks for assessing safety and labeling products.

Engaging with industry to advance alternative proteins

We conduct research and share insights to educate the public on alternative proteins and champion their adoption by the food industry, including manufacturers, retailers, restaurants, investors, and more.

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