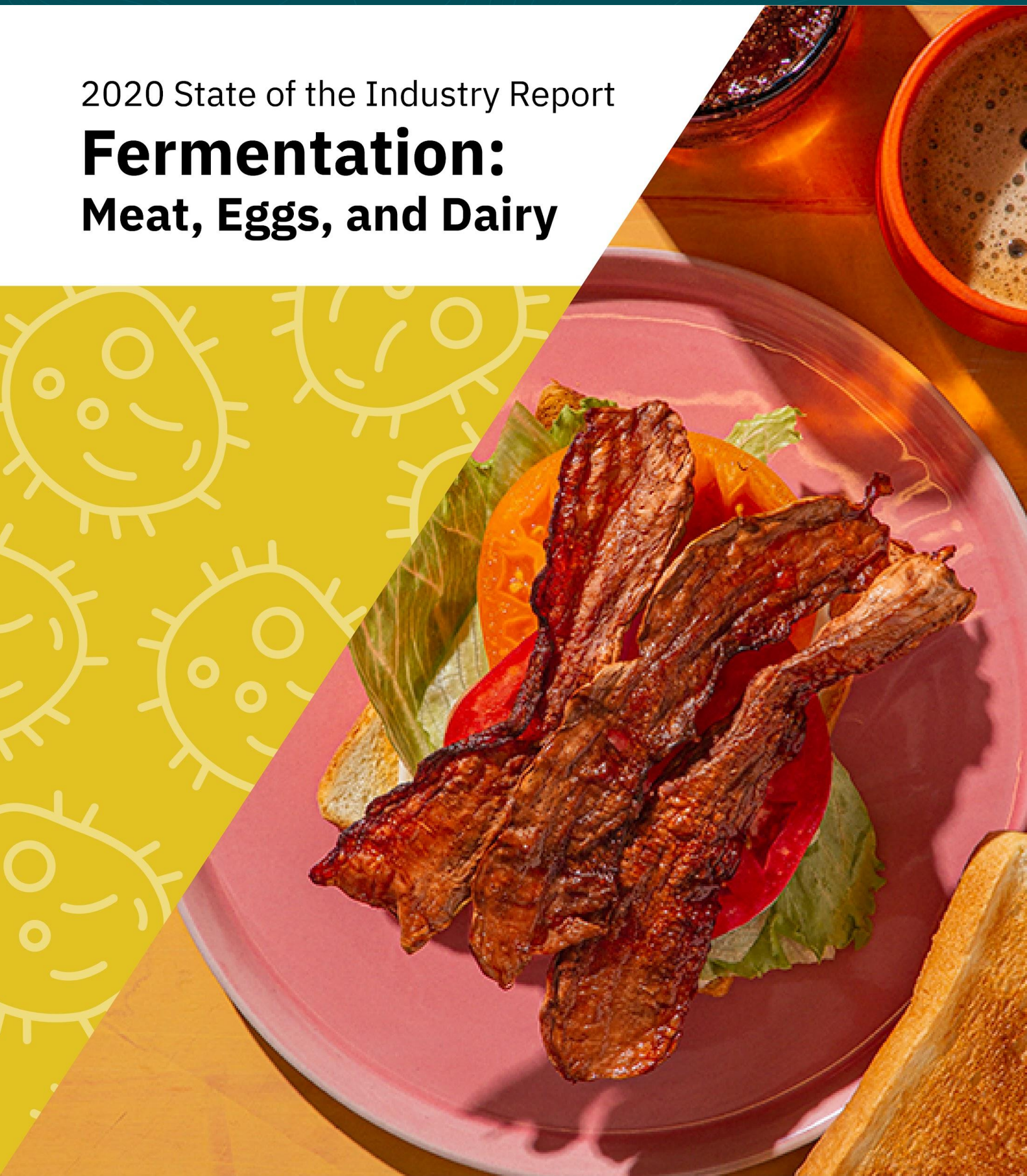
Good Food Institute

2020 State of the Industry Report

Fermentation:
Meat, Eggs, and Dairy



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The Good Food Institute is a 501(c)3 nonprofit organization developing the roadmap for a sustainable, secure, and just protein supply. We identify the most effective solutions, mobilize resources and talent, and empower partners across the food system to make alternative proteins accessible, affordable, and delicious.

This report, as well as all of GFI's research, data, and insights, is made possible by gifts and grants from our global family of donors.

Executive summary

Image credit: Perfect Day

Executive summary

GFI is pleased to offer this report as a snapshot of major 2020 developments in fermentation as an enabling technology for the alternative protein industry. Fermentation will be a key component in the shift toward alternative proteins, and this report provides an overview of the companies, technologies, and investments driving this sector of the industry.

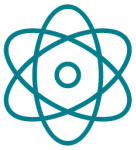
Fermentation-enabled proteins year at a glance

Commercial landscape. The commercial landscape expanded substantially in 2020:

- Thirteen startups dedicated to the use of fermentation for alternative proteins launched, along with new suppliers focused on fermentation-enabled alternative protein ingredients.
- Activity in precision fermentation increased, with nine of the 13 new companies focused on precision fermentation, three on biomass (an area with significant activity in 2019), and one on traditional fermentation.
- Fifty-one known companies are now dedicated to fermentation-enabled alternative proteins, an increase of 16 percent from 2019, and more than 30 others have a business line in alternative protein fermentation.

Products. 2020 saw the introduction of the first dairy product made through precision fermentation. Perfect Day's commercial ice cream launches, including CPG brand Brave Robot, represent the first time consumers have been able to buy precision-fermentation-enabled animal-free dairy made with real milk proteins.

Investments. Investment in fermentation technology skyrocketed in 2020. Fermentation companies raised $587 million, a greater than twofold increase from 2019 that represents 57 percent of all-time sector funding.



Science and technology. Alternative protein companies launched new R&D centers and production facilities, and GFI's research grant program funded several studies on fermented oat proteins and fermented flavor bases for alternative proteins.

Government and regulation. Governments around the world recognized the potential of fermentation technologies in the development of sustainable protein and rewarded multiple companies with grant funding in 2020. Perfect Day announced a collaboration with Singapore's Agency of Science, Technology and Research (A*STAR) to build a research and development center.

Introduction

Image credit: Meati

Section 1: Introduction

In 2020, fermentation joined plant-based and cultivated proteins as the third technological pillar of the alternative protein revolution. Although fermentation has been used to make food and beverages for millennia—everything from beer to kimchi—2020 was a major inflection point in its range of applications and possibilities for use in the agrifood industry.

Combining the indigenous wisdom of traditional food fermentation, the lessons of scale learned from biofuels, the precision pioneered by biopharmaceuticals, and the breakout success of the plant-based meat industry, fermentation has emerged as a powerful technological platform for taking alternative protein products to the next level.

More than 80 percent of the companies devoted to fermentation-enabled alternative proteins fermentation applications have formed in just the past five years. But the industry's nascency belies powerful potential, which has prompted many entrepreneurs, investors, scientists, governments, and industry media outlets to take notice. In November 2020, the World Economic Forum **flagged fermentation as a key global innovation area**:

> **Fermentation presents an opportunity to fundamentally change the way the world eats and improve global human and environmental health and the economy.**

In October 2020, GFI held the first international conference focused exclusively on the role of fermentation in alternative proteins. The GFI 2020 Symposium on Fermentation attracted more than 3,000 registrants across 50 countries. Attendees included investors, academics, students, startup CEOs, celebrity chefs, and leaders from the world's largest meat, food, and beverage companies. Recordings from the symposium sessions are available on **GFI's YouTube channel**. In September 2020, GFI Consultancy, GFI's strategic partner in mainland China, held the **first Chinese conference** on fermentation and cultivated meat. The invitation-only event drew 80 scientists, investors, food companies, and policymakers to discuss the fermentation sector's role in alternative proteins and the Chinese food industry.

In 2020, fermentation-enabled alternative proteins emerged as a cohesive industry, comprising companies with a shared mission, common language, and record-breaking amount of venture capital investment. This report gives the rundown of major happenings in the fermentation-enabled alternative protein industry in 2020.

"Microbial fermentation has been used for years in the food industry to produce ingredients such as enzymes and in the biopharma industry to produce vaccines and drugs. This same technology is now being applied to the alternative protein industry to enable a new generation of ingredients and products with enhanced sensory and functional attributes. I believe fermentation will be central to the future of alternative proteins, and a lot of the industry growth over the next 10 years will be the result of innovations in this segment. Industry leaders appear to believe so too, with companies like AB InBev, DuPont, and Danone making notable investments in the space. "

—Caroline Bushnell, director of corporate engagement at The Good Food Institute

The definition and role of fermentation in the context of alternative proteins

Fermentation in the alternative protein industry refers to cultivating microbial organisms for the purpose of processing a foodstuff or food ingredient; obtaining more of the organism itself as a primary source of protein; or deriving specialized ingredients, such as flavorings, enzymes, proteins, and fats, for incorporation into plant-based products or cultivated meat.

The alternative protein industry uses fermentation in three primary ways:

1) **Traditional fermentation** has been used for thousands of years to produce items such as bread and beer. It uses intact live microorganisms to modulate and process plant-derived ingredients, resulting in products with unique flavor and nutritional profiles and modified texture.
2) **Biomass fermentation** leverages the fast growth and high protein content of many microorganisms to efficiently produce large quantities of protein. This biomass serves as either the predominant ingredient of a food product or one of several primary ingredients in a blend.
3) **Precision fermentation** uses specially designed microbial hosts as "cell factories" for producing specific functional ingredients. These ingredients are powerful enablers of improved sensory characteristics and functional attributes of plant-based products or cultivated meat.

For more background on fermentation, its definitions, and its applications, check out GFI's **fermentation** page.

Harnessing Microbial Hosts as Cell Factories session from the GFI 2020 Symposium on Fermentation. The panelists are (clockwise from top left) Monica Watrous (managing editor of *Food Business News*), Ranjan Patnaik (chief technology officer of Clara Foods), Michael Leonard (chief technology officer of Motif FoodWorks), and Tim Geistlinger (chief science officer of Perfect Day).

Commercial landscape

Image credit: Tofurky

Section 2: Commercial landscape

Across the supply chain, fermentation as an enabling technology for alternative proteins is drawing increased interest. At least 51 companies focus primarily on fermentation for alternative protein applications (Table 2). As interest in alternative proteins has grown in the past several years, many additional companies, including life science, pharmaceutical, nutrition, agricultural, and big food companies, have diversified and created business initiatives in the alternative protein industry (Figure 5).

Overview

2020 saw rapid growth in the commercial landscape of fermentation-enabled alternative protein:

- Thirteen dedicated startups launched in the fermentation-enabled alternative protein space, including Chunk, Imagindairy, and Fybraworks Foods. See Table 2 for the full list.
- While 2019 was a breakout year for biomass startups (eight of 14 startups), 2020 saw a surge in precision fermentation activity, with nine of the 13 new companies focused on precision fermentation, three on biomass, and one on traditional fermentation.
- Fifty-one known companies are now dedicated to some of the newest and most promising applications for fermentation—creating proteins, lipids, and functional ingredients for plant-based products and cultivated meat. See Table 2 for the full list.
- More than 30 known companies have a business line in fermentation-enabled alternative protein, including Richcore, Shiru, and Arbiom. See Figure 5 for the full list.

A note on Covid-19

"2020 was a year of reckoning. Our demand for meat has pushed our natural environment beyond the limit of what can be safely sustained. Covid-19 showed us how resilient we can be when faced with adversity, but it also highlighted the terrible issues affecting our food system—while many people were going hungry, our paralyzed supply chain dealt with surplus livestock in unthinkable ways. In people's minds, meat alternatives have become a necessity, not just simply an added choice, and fermentation science is poised to enable the next generation of alternative proteins to enter the market."
—Abril Estrada, Wild Earth

The full story of fermentation-enabled meat, eggs, and dairy in 2020 cannot be told without accounting for the effects of Covid-19:

- The pandemic, particularly in its early days, affected the ability of scientists to conduct bench research by limiting both lab time and sourcing of important reagents.
- Timelines for scientific milestones were extended.
- Go-to-market strategies were thrown into uncertainty as the food system underwent massive shifts.
- Key-input supply, production-space access, and product distribution experienced interruptions.

Despite these constraints, companies continued to meaningfully advance both R&D and commercialization efforts. The industry's impressive 2020 funding totals, profiled in the forthcoming **investments** section, signal growth and opportunity. As the full story of Covid-19's impact on the industry continues to unfold, GFI remains confident that modernizing meat production with alternative proteins is an important step toward **avoiding future pandemics**.

While fermentation initiatives are generally divided into products of traditional fermentation, biomass, and functional ingredients (produced via precision fermentation), the line between biomass and functional ingredients is not always clear. Some biomass products also impart special functionality to the end product, and some functional ingredients make up a significant portion of an end product's mass. These proteins, as well as fats and other compounds, are best considered along a spectrum. Figure 2, an inexhaustive "mind map" of the fermentation sector as it relates to alternative proteins, highlights this landscape of possibilities for fermentation-enabled proteins.

Figure 1: A conceptual landscape of fermentation-derived and fermentation-enabled products

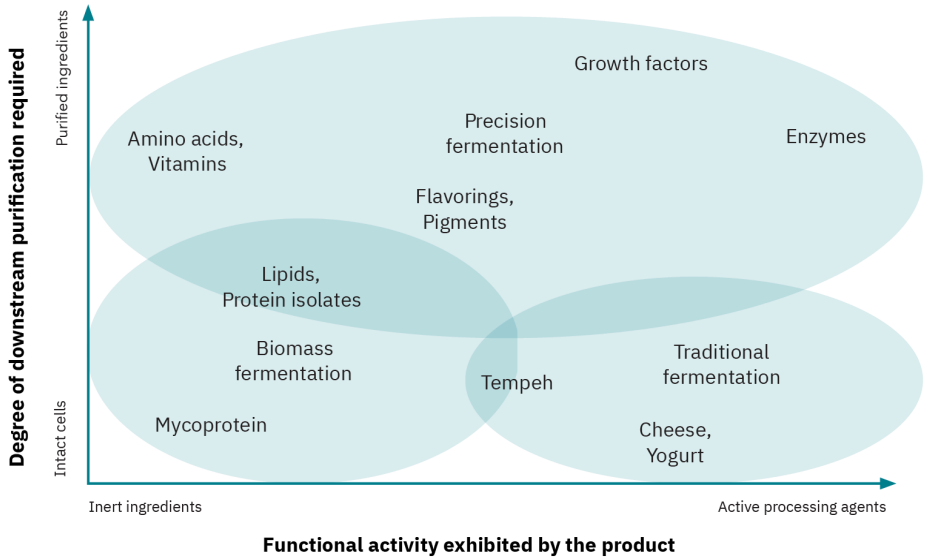
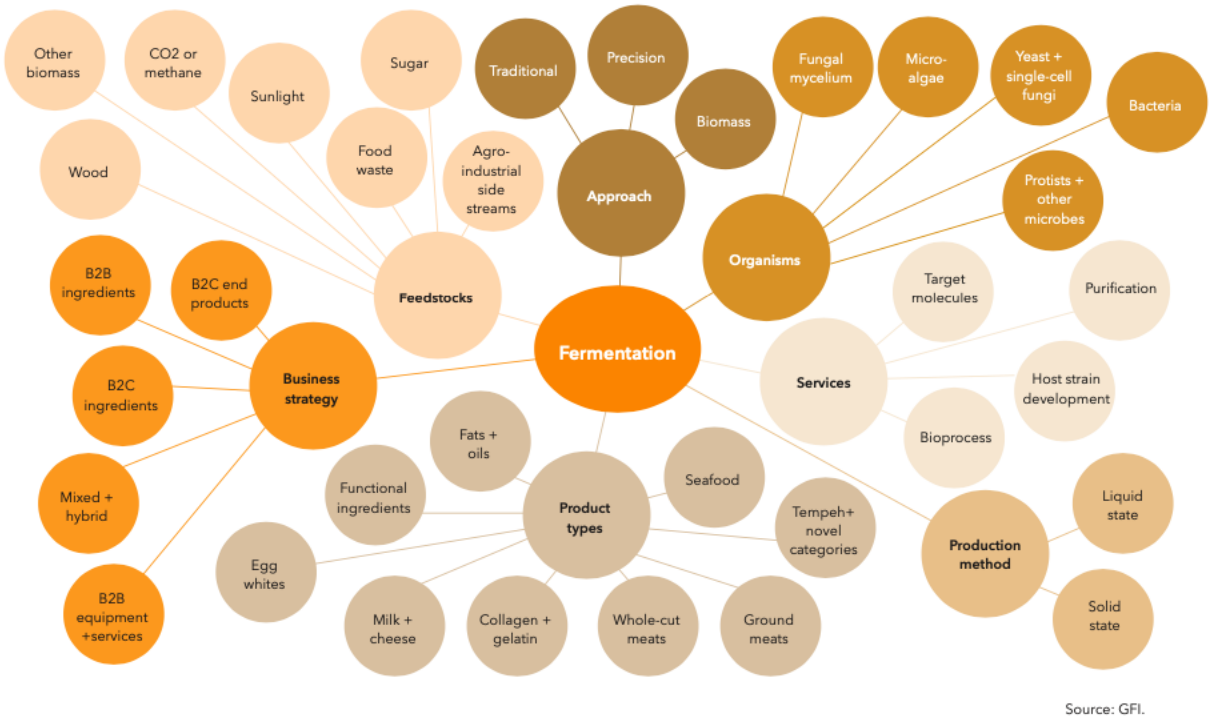


Figure 2: Mind map of fermentation in the alternative protein industry



A visual representation of the landscape of fermentation in alternative proteins. Source: GFI.

The following graphics provide an overview of companies working in fermentation-enabled alternative protein as either their core function (Table 2) or a broader business initiative (Figure 5). All company references are purely illustrative, and while intended to be comprehensive, these lists are not exhaustive. Rather, they offer a snapshot of the range of companies and technology applications for fermentation. Because of fermentation technology's broad uses, Table 1 sets parameters for inclusion in this section and in Section 4 on investments.

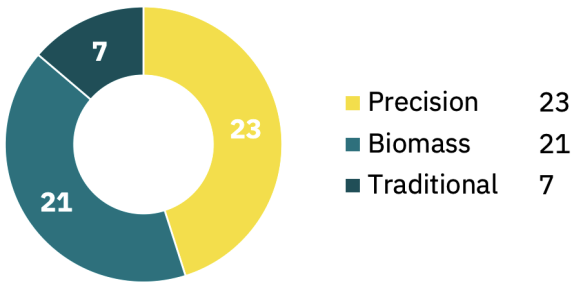
Table 1: Types of companies included in report scope

Included	Not included
• Microbes (bacteria, microalgae, protists, and single-cell fungi) to produce edible biomass or functional ingredients for plant-based meat, eggs, and dairy, as well as functional ingredients for meat cultivation (such as growth factors). • Mycelium to produce edible biomass or functional ingredients for plant-based meat, eggs, and dairy. • Fermentation to produce pet food (which is highly relevant to human food applications).	• Fermentation to produce food ingredients that are not replacements for meat, eggs, or dairy (such as sweeteners and protein powders). • Fermentation to produce food items other than for humans or pets. • Fermentation to produce molecules for other non-food applications (such as biofertilizer, farmed animal feed, aquaculture feed, chemicals, biofuel, cosmetics, and biologics). • Large corporations with R&D that is not publicly disclosed, as well as startup companies in "stealth mode." • Nut-based and other fermented cheese and butter (such as **Miyoko's**), which are covered in GFI's **state of the industry report on plant-based meat, eggs, and dairy**. • Tempeh and other traditional fermented foods, such as sourdough or kimchi. • Mushrooms (the fruiting bodies of some fungi). • Macroalgae (such as kelp, seaweed, dulse, and sea vegetables). • Nonprofit organizations and academic research labs. Note: Companies with current applications of fermentation technology for alternative proteins and lipids as part of a broader business are included in Figure 5 but not in investment calculations.

Fermentation for alternative protein end products

Of the 51 companies focused primarily on fermentation for alternative protein applications, 21 are biomass companies, 23 are precision fermentation companies, and seven are traditional fermentation companies.

Figure 3: Number of companies by type of fermentation



These 51 companies use diverse production platforms, organisms, and feedstocks to deliver protein, fat, and functional elements—such as structure and texture—for a broad set of animal-free meat, egg, and dairy products as shown in Table 2.

Table 2: Companies focused on fermentation for animal-free meat, eggs, and dairy (alphabetically ordered)

Company	Brief description	Technology category	Location	Total disclosed funding ($M)	Founders	Year founded
3F Bio	Mycoprotein production process for meat alternatives and protein ingredients	Biomass	Glasgow, Scotland, UK	$9.22	Craig Johnson, David Ritchie, Jim Laird	2015
Afineur	“Cultured protein” for plant-based foods	Traditional	New York, NY, USA	$0.22	Camille Delebecque, Sophie Deterre	2014
Air Protein	Food-grade protein from CO_2	Biomass	Berkeley, CA, USA	$32.11	Lisa Dyson	2019
Algama	Platform for microalgae-based plant-based foods and ingredients (including egg, seafood, meat, and dairy replacements)	Biomass	Paris, France	$9.59	Alvyn Severien, Gaëtan Gohin	2016
AquaCultured Foods	Whole-cut seafood analogues	Biomass	Chicago, IL, USA	–	Anne Palermo, Brittany Chibe	2020
Atlast Food Co.	Mycelium-based whole-cut meats (starting with bacon)	Biomass	Green Island, NY, USA	$7.00	Eben Bayer, Steve Lomnes, Russell Hazen, Gavin McIntyre, Andy Bass, Alex Carlton	2019
Bolder Foods	Combined fermentation and plant-based technologies to create biomimicked dairy products	Biomass	Brussels, Belgium	–	Ilana Taub, Michael Minch-Dixon	2020
Bond Pet Foods	Microbially produced animal proteins for pet food	Precision	Boulder, CO, USA	$2.0	Rich Kelleman, Pernilla Turner Audibert	2015
Brevel	Microalgae cultivation using internal illumination of cultures by sunlight transported via optical fibers	Biomass	Israel	Undisclosed	Ido Golan, Yonatan Golan	2016
Change Foods	Protein and fat production for dairy (starting with cheese)	Precision	San Francisco, CA, USA	$2.1	David Bucca	2019
Chunk	Whole-cut meat analogues processed with solid-state fermentation	Traditional	Tel Aviv, Israel	–	Amos Golan	2020

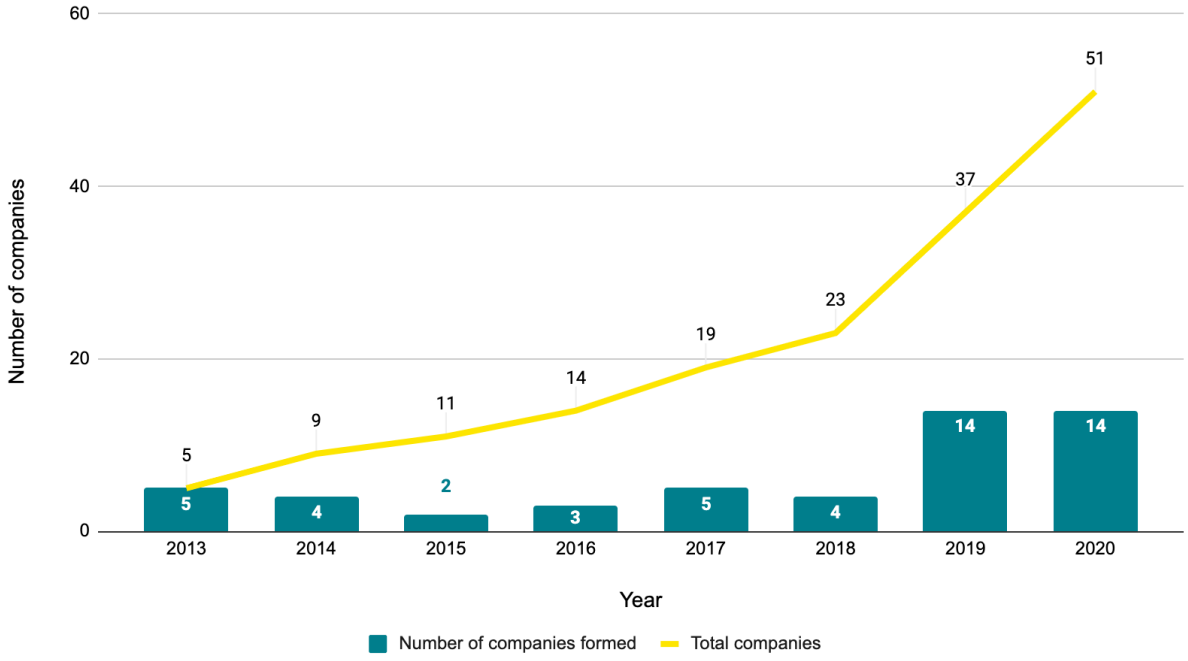
Circe	Fermentation of dairy triglycerides and synthetic polymers (spinout of the Wyss Institute)	Precision	Boston, MA, USA	Not profiled	Shannon Nangle, Marika Ziesack, Kevin McDonough	2020
Clara Foods	Egg proteins through fermentation	Precision	San Francisco, CA, USA	$71.80	Arturo Elizondo, David Anchel	2014
Cultivated	Microbial fermentation to develop alternatives to dairy products	Precision	Lausanne, Switzerland	Not profiled	Tomas Turner, Denis Joly	2020
Final Foods	Whey proteins for cheese produced by yeast in open-source bioreactor	Precision	Santa Clara, CA, USA	–	Julian Ramirez, Marco Graziano, Barbara Dunn	2020
Foods Myco Mizoram	Mycelium-derived meat products	Biomass	Aizawl, India	Not profiled	Henry Saingura	2019
Formo	Microbial fermentation to produce milk proteins for dairy products	Precision	Berlin, Germany	$4.43	Raffael Wohlgensinger	2019
Fumi Ingredients	Egg replacement ingredient through microbial fermentation	Precision	Wageningen, Netherlands	$0.60	Edgar Suarez Garcia, Corjan van den Berg	2019
Fybraworks Foods	Mycelium as an expression platform for animal muscle proteins for meat alternatives	Precision	Minneapolis, MN, USA	$0.08	Chenfeng Lu, David Liu	2020
Harmony	Infant formula using human milk proteins produced via fermentation	Precision	Boston, MA, USA	Not profiled	Wendel Afonso	2020
Helaina	Infant formula using human milk proteins produced via yeast	Precision	New York, NY, USA	$4.41	Laura Katz	2020
Imagindairy Ltd.	Development of milk proteins with AI platform and fermentation	Precision	Israel	$2.35	Eyal Afergan, Tamir Tuller	2020
Kernel Mycofood	Decentralized production of mycoprotein	Biomass	Buenos Aires, Argentina	–	Horacio Acerbo, Martín Blasco, Lucas Gago, Sebastián Taito, Miguel Neumann	2019
Kinoko-Tech	Mycelium-derived meat products	Biomass	Rehovot, Israel	Undisclosed	Daria Feldman, Hadar Shohat, Jasmin Ravid	2019ff
Meati (formerly Emergy Foods)	Whole-muscle meats made from mycelium, including steak, chicken, and fish	Biomass	Boulder, CO, USA	$33.00	Justin Whiteley, Tyler Huggins	2016

The Mediterranean Food Lab	Novel methods inspired by traditional fermentation technologies to produce plant-based products and improve the sensory qualities of a wide range of plant-based meat and other foods	Traditional	Tel Aviv, Israel	$0.12	B.Z. Goldberg, Omer Ben Gal	2019
More Foods	Meats utilizing yeast proteins	Biomass	Tel Aviv, Israel	–	Leonardo Marcovitz	2019
Motif FoodWorks	Functional ingredients for plant-based foods	Precision	Boston, MA, USA	$117.50	Jonathan McIntyre	2018
Mushlabs	Mycelium-based ingredients for meat alternatives	Biomass	Berlin, Germany	$11.94	Mazen Rizk	2018
Mycorena	Fungi-based protein for food applications (Swedish meatballs) using industrial side streams	Biomass	Gothenburg, Sweden	$1.78	Ramkumar Nair	2017
MycoTechnology	Fungi-based bitter blocker ingredient and protein	Traditional	Aurora, CO, USA	$81.67	Alan Hahn, Brooks J. Kelly, James P. Langan, Peter Lubar	2013
Mycovation	Meat analogues from mycelium	Biomass	Singapore	–		2020
Nature's Fynd	Edible protein through cultivation of extremophile organisms through liquid air interface fermentation	Biomass	Chicago, IL, USA	$158.00	Thomas Jonas, Matthew Strongin, Mark Kozubal	2014
New Culture	Casein for cheese production (starting with mozzarella)	Precision	San Francisco, CA, USA	$8.70	Inja Radman, Matt Gibson	2018
NextFerm	Novel active ingredients (whey-like protein) from non-GMO yeast fermentation	Precision	Yokneam, Israel	$5.00	Boaz Noy, Tzafra Cohen	2013
Nourish Ingredients	Fermentation-derived fats for meat, dairy, and fish alternatives	Precision	Brisbane, Australia	–	Ben Leita, James Petrie	2019
novacca	Milk proteins using fermentation platform	Precision	Nivå, Denmark	Not profiled		2018
Perfect Day	Milk proteins using fermentation platform	Precision	Berkeley, CA, USA	$361.48	Perumal Gandhi, Ryan Pandya	2014
PLANETARIANS	Fermentation of plant-based meats from sunflower cakes to improve functionality	Traditional	Palo Alto, CA, USA	$0.90	Aleh Manchuliantsau, Anastasia Tkacheva	2017
Prime Roots	Meat analogues made from mycoprotein	Traditional	San Francisco, CA, USA	$18.54	Joshua Nixon, Kimberlie Le	2017

Provenance Bio	Development of synbio tools for use in creating animal proteins (working on collagen for cultivated meat)	Precision	San Francisco, CA, USA	Undisclosed	Michalyn Andrews, Zev Gartner, John Dueber, Christian Ewton	2020
Pura	Mycoprotein production and fermentation to enhance plant-based foods	Biomass	Inarzo, Italy	–	Stefano Babbini	2019
Quorn	Pioneering mycoprotein meat alternatives	Biomass	Stokesley, England, UK	–	Lord Rank	1985
Remilk	Fermentation-derived dairy molecules	Precision	Tel Aviv, Israel	$11.32	Aviv Wolff, Ori Cohavi	2019
Solar Foods	Electrolysis-enabled novel protein under Solein brand for food ingredients, plant-based meat, and cultivated meat	Biomass	Helsinki, Finland	$26.10	Pasi Vainikka, Juha-Pekka Pitkänen	2017
Sophie's BioNutrients	Microalgae R&D to create proteins for plant-based meat and dairy	Biomass	Singapore	$1.17	Eugene Wang, Kirin Tsuei, Barnabas Chan	2013
The Protein Brewery	Fungi-based protein to replace meat under the Fermotein brand and fungi-produced egg proteins	Biomass	Breda, Netherlands	$25.87	Wim de Laat	2019
Those Vegan Cowboys	Production of recombinant casein to make vegan cheese (from the founders of The Vegetarian Butcher)	Precision	Flanders, Belgium	–	Jaap Korteweg, Niko Koffeman	2020
Triton Algae Innovations	Production of heme and other meat-like compounds from microalgae for plant-based meat applications	Precision	San Diego, CA, USA	$5.00	Miller Tran	2013
Wild Earth	Fermentation-derived pet food	Traditional	Berkeley, CA, USA	$15.55	Ryan Bethencourt	2017
Yeap	Meat analogues made from yeast	Biomass	Ashdod, Israel	–	Didiber Toubia, Jonathan Goshen, Dominik Grabinski	2020

Notes: The investment data from this section, sourced from GFI's PitchBook analysis—the methodology we profile in the **investments** section—reflects industry developments through December 31, 2020. "Total disclosed funding ($M)" refers to invested capital as defined in "Box 2: Data collection methodology." A dash under this column heading indicates that the company in the corresponding row is not associated with any disclosed funding rounds in PitchBook. "Undisclosed" means that the company has raised an investment round, but the amount is undisclosed in PitchBook and thus not included in the funding totals. Finally, "Not profiled" means that the company itself is not yet covered by PitchBook, and thus the company's financing activity is unknown.

Figure 4: Number of companies in fermentation-enabled alternative proteins (2013–2020)



Source: GFI company database.

"[In 2020] large consumer product companies became believers in the long-term market draw of alternative proteins, driving both a new wave of startup companies and robust venture funding. This has converted the industry from a technology-driven push to a market-induced draw, a more sustainable and financeable model."

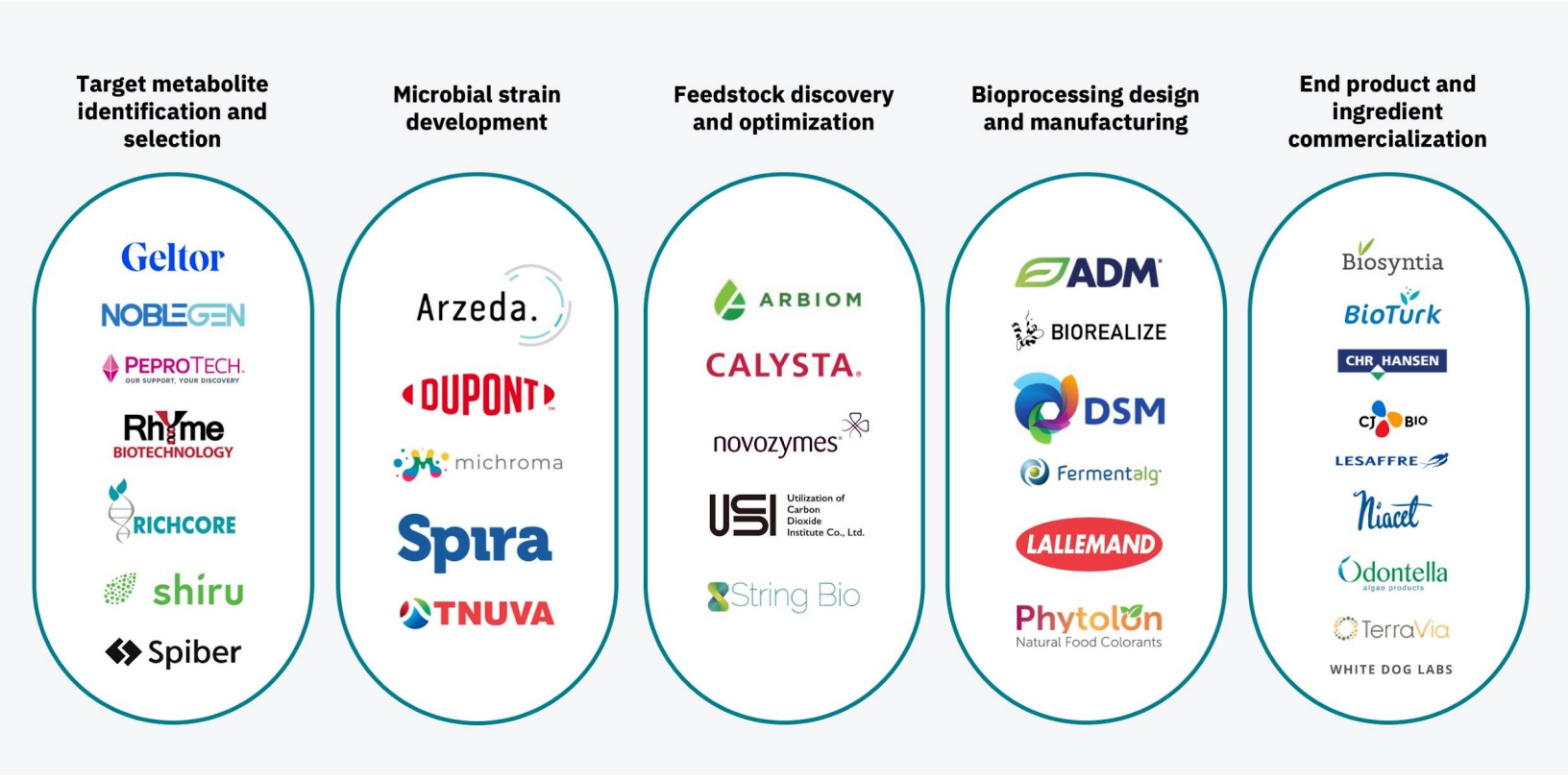
—Mark Warner, Warner Advisors

Fermentation initiatives for animal-free meat, eggs, and dairy

More than 30 companies have a commercial initiative in fermentation-enabled alternative proteins. These companies have diverse focuses within the technology value chain, and some companies, such as Superbrewed Food (formerly White Dog Labs) and Tnuva, are working across value chain categories. Others are specializing in the following key value chain segments, also represented in Figure 5, all of which are important to advancing fermentation as an alternative protein technology:

- Target metabolite identification and selection.
- Microbial strain development.
- Feedstock discovery and optimization.
- Bioprocessing design and manufacturing.
- End product and ingredient commercialization.

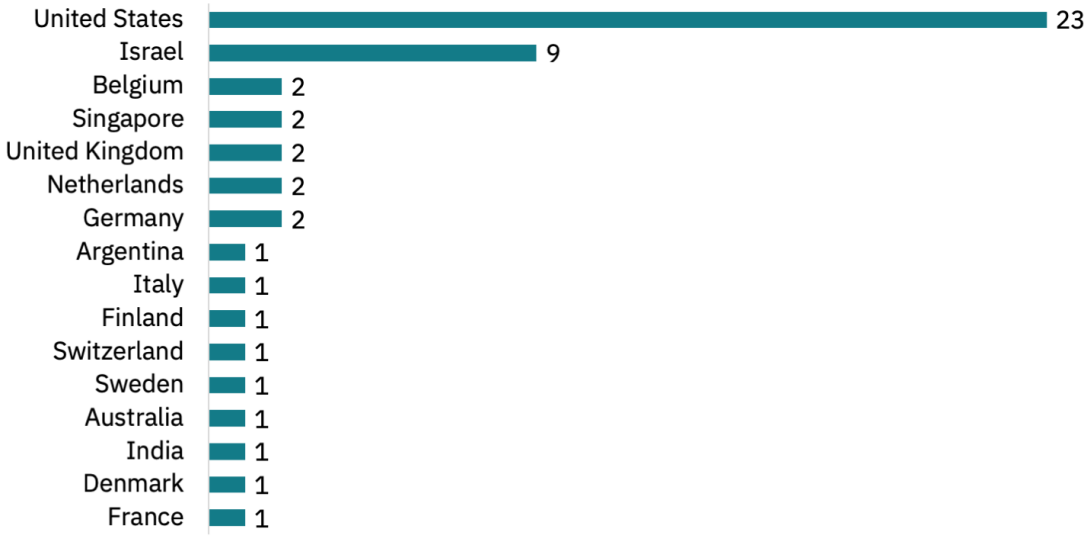
Figure 5: Companies with fermentation initiatives for animal-free meat, eggs, and dairy



You can learn more about these companies in the **GFI company database**. *Are we missing something? Let GFI know by filling out our* **company database edits form**.

The fermentation industry spans the globe. Companies involved in fermentation for alternative protein applications operate in at least 16 countries. The largest concentration of companies is in the United States with 23, followed by Israel with nine. Of the 13 companies formed in 2020, six are in the United States, and the rest are in Belgium, Israel, Switzerland, and Singapore.

Figure 6. Geographic distribution of fermentation-enabled alternative protein companies by headquarters



Are we missing something? Did we get something wrong? We'd appreciate your feedback via **this form**.

Products

Image credit: Quorn

Section 3: Products

Culinarians, ingredient companies, and food manufacturers increasingly recognize the potential of targeted fermentation to endow foods with unique flavor, texture, and nutritional attributes. Along with advances in biotechnology, data analysis, and industrial design, this potential has established fermentation as an indispensable platform for innovations in both ingredients and primary protein production. And 2020 saw the development and launch of more alternative protein products created with this technology, including several industry firsts detailed in this section.

Consumer product categories: Fermentation allows for a huge diversity of products

In 2020, companies advanced applications of fermentation technology to produce ground meat products, whole-cut meats, eggs, milk, cheese, gelatin, seafood, fats, oils, pet food, and more. Fermentation is also enhancing plant-based products across all these categories.

Ground meat

- Sweden's Mycorena **soft-launched** their line of fungal protein Swedish meatballs in local stores. Other companies, such as 3F Bio, are also developing fungi protein products.
- Planterra, a plant-based meat subsidiary of the world's largest meat producer, JBS, introduced their first line of products under the brand OZO, which features pea and rice protein fermented with shiitake mycelia from MycoTechnology. Planterra launched an **online store** for OZO and gained significant distribution at large grocers, such as Safeway and Kroger.
- Impossible Foods, which uses precision fermentation to produce their signature leghemoglobin ingredient, rapidly expanded their U.S. retail distribution and added **distribution** in Singapore and Hong Kong.
- **Better Nature**, which makes animal-free meats from tempeh, announced their new Better Burger, made through traditional fermentation, at the GFI 2020 Symposium on Fermentation.
- Noma debuted a carryout **fermentation-enabled quinoa tempeh burger**.
- Fermentation pioneer Quorn **rolled out their mycoprotein-powered chicken in U.S. restaurant chain Hooters** in one of the first major foodservice launches of animal-free chicken.

Outside tempeh and other fermented foods that are not intended to fully mimic the sensory properties of animal products, ground products make up the bulk of fermentation-enabled offerings widely available to consumers. However, additional product formats are launching with increasing frequency.

Whole-cut meats

Fermentation presents opportunities for enhanced texture in whole-cut products without the extrusion on which plant-based products have traditionally depended. Creating animal-free whole cuts and cutlets is a massive market opportunity, as whole-cut products (such as fillets, bone-in cuts, and ham) are the **highest-margin and most desirable segment** of the **$1.7 trillion** global meat market. 2020 brought major developments in whole-cut products:

- Colorado-based Meati Foods launched their line of whole-cut steak and chicken products made through **submerged fermentation** at a Colorado restaurant.
- Atlast Food Co., which produces whole-cut meats, introduced their brand **MyBacon**. Atlast also offers private labeling and announced in December that they had **presold all planned capacity through 2023**.
- In March, Prime Roots, which deploys mycoprotein to create a variety of products for direct-to-consumer sale, sold out their soft-launch inventory **within hours**. By the end of 2020, Prime Roots had launched animal-free bacon, chicken, pork, and beef products in their **online store**.

Eggs and egg replacements

A small crop of companies has emerged to crack animal-free eggs by using fermentation to produce their functional components in a better way.

- Noblegen introduced "**the egg**," a protist-derived, powdered whole-egg replacement, in early 2020.
- Also early in the year, Clara Foods announced the forthcoming launch of their fermentation-enabled egg whites, as well as a partnership with Ingredion to **sell the world's first animal-free pepsin enzyme**.

Dairy

Fermentation also holds disruptive potential for dairy products. 2020 saw several notable fermentation-powered dairy developments:

- Tofurky sister company Moocho **launched a line of dairy-free cheese shreds powered by fermented cultures** and fava bean protein.
- Perfect Day commercially debuted animal-free ice cream using their recombinant whey protein, including a retail launch and introductions at multiple ice cream chains.

Box 1: Fermentation-enabled milk proteins come to market

Precision fermentation had a significant market test in 2020 with the launch of several products containing Perfect Day's fermentation-enabled milk proteins. **Perfect Day**, formed in 2014 by Isha Datar of New Harvest and New Harvest community members Ryan Pandya and Perumal Gandhi, is the first company to bring to market real milk proteins—whey—for food applications using microbes rather than mammary glands. In early 2020, Perfect Day **partnered** with San Francisco ice cream producer Smitten to sell animal-free ice cream—the first such animal-free dairy ice cream on the market—on Smitten's local and regional direct-to-consumer platform. Later in the year, Perfect Day inked deals with ice cream chains **N!CK'S** and **Graeter's** to further expand the company's reach. Perfect Day also spun out **The Urgent Company**, which started a new animal-free ice cream brand, **Brave Robot**. Launches like these will enable a new generation of biomimicking animal-free cheese, ice cream, yogurt, and butter. Other companies, including **New Culture**, **Change Foods**, Cultivated, and **Formo**, recently emerged to create dairy proteins and fats that will usher in a wave of plant-based, precision-fermentation-enabled dairy.

Perfect Day's animal-free ice cream made in partnership with Smitten. | Image credit: Perfect Day

Gelatin

Gelatin is partially degraded collagen protein, traditionally derived from animal connective tissue as a byproduct of meat rendering. Because of its gelling properties, gelatin is used in many food and cosmetic applications. 2020 brought these notable developments:

- **Jellatech** formed to commercialize fermentation-enabled jellyfish collagen for food and cosmetic applications.
- Geltor closed a $91.3 million Series B funding round after they **developed a plant-based, fully biocompatible human elastin** for the skincare market.

Seafood

One of the least developed areas of alternative proteins is plant-based seafood. Quorn's **fishless fingers** are the only widely available fermentation-enabled seafood product. Fermentation, particularly with microalgae, may hold the key to unlocking this category. 2020 was marked by great promise:

- **Odontella**, which makes a structured salmon analogue using seaweed and microalgae, announced two contracts with food retailers for at least 500,000 servings.
- Meati posted an Instagram **teaser** on World Oceans Day: a mycelium-based flaky fish in a basket of fish and chips.
- 3F Bio **announced** a prototype mycoprotein tuna steak produced via a 3D printer made by Natural Machines.
- Good Catch, which uses microalgal omega-3 oil in their plant-based tuna, **expanded distribution** in the United States and extended it to Europe.

See GFI's white paper ***An Ocean of Opportunity*** to learn more about the potential of seafood alternatives.

Fats and oils

Fats are key contributors to the sensory experience of eating meat, egg, and dairy products. By using microbial fermentation, companies can produce a wide array of fats—including fats that are critical to the nutrition, sensory characteristics, or functionality of animal products but challenging to source from the plant kingdom. The most notable on-market example is microalgae cultivation to produce algal omega-3 fatty acids, such as EPA and DHA, which are not produced by terrestrial plants. Companies such as Algarithm, DSM, iWi, and Corbion produce algal- or fungal-derived omega-3s. The category enjoyed breakthrough investment success in 2020:

- **C16 Biosciences**, which uses microorganisms with altered lipid synthesis pathways to produce desirable fats, **announced $20 million in Series A funding** from backers including Bill Gates-led Breakthrough Energy Ventures.

Pet food

Pet food is a promising application for fermentation due to fermentation's ability to create proteins that are scarce in plants but desirable for animal-free pet foods. Pet food is not only a **$30 billion market** but the cause of about **25%–30% of the environmental impact of eating meat** in the United States. Human-food producers can also leverage research and technology developed for pet food applications. 2020 saw significant developments in fermentation-enabled pet food:

- Wild Earth, a pet food and dog treat company, **expanded** their products to the Indian market.
- Bond Pet Food, which uses microbes to produce specific animal muscle proteins, **introduced** their first product: a high-protein dog treat produced with a novel strain of yeast.

"2020 saw the blossoming of fermentation as the third pillar of alternative proteins due to a number of converging factors globally. The technology and the boundless potential of microbes became more widely understood and democratized, fermentation investments hit record heights, multiple startups emerged in various countries and categories, and alternative proteins continued to rapidly rise in prominence in the broader market. Many are looking towards future technologies for improved performance and to help solve for the limitations of existing products experienced by the flexitarian consumer."

—David Bucca, Change Foods

The role of incumbents in enzyme solutions and scaling

Incumbents in the B2B fermentation industry include manufacturers of food processing enzymes, flavoring ingredients, vitamins, and live microorganisms for fermented foods such as cheese, yogurt, and preserved meat. These companies, which include Cargill, DuPont, AB Enzymes, Biocatalysts, Novozymes, Kerry, ADM, DSM, Amano, and Ajinomoto, have deep expertise in enzyme development, strain development, and large-scale manufacturing. While the alternative protein industry is not a major fraction of their business, many of these companies recognize the growing importance of this new application area and are developing novel solutions accordingly:

- Novozymes expanded their marketing of enzymes for improving **flavor and functionality** of plant proteins.
- DSM launched a **portfolio of enzyme solutions** targeting plant-based dairy product developers.

Emerging B2B companies as suppliers and service providers for the alternative protein industry

The majority of B2B companies using fermentation for alternative protein products position themselves as ingredient suppliers that empower B2C companies to improve their branded products. Scale, cost, and functionality are these companies' core drivers for differentiation and adding value to the alternative protein ecosystem. 2020 saw several developments in the B2B supplier and service subsector:

- Producing natural, microbe-derived flavoring solutions and bulk proteins for use in consumer-facing products.
    - **MycoTechnology**'s pea and rice protein fermented by shiitake mycelia **launched in OZO brand plant-based meat by Planterra, a JBS subsidiary**.
    - UK retailer Marks & Spencer **announced a vegan range that uses 3F Bio's mycoprotein**.
    - Ginkgo Bioworks spinoff **Motif FoodWorks invested in expanded manufacturing capacity** in advance of commercial-scale production of their first product, which adds meaty flavor to beef alternatives.
- Leveraging biotechnology to produce genuine animal proteins in microbial or mycelial hosts.
    - Geltor completed a Series B funding round in July worth $91.3 million and in November **announced a new Ingredients-as-a-Service platform**, adding the first biocompatible human elastin, Elastapure, to their product portfolio.
- Providing services and technology development for B2B or B2C fermentation companies.
    - **Culture Biosciences piloted a new high-throughput mammalian cell version** of their bioreactors-on-demand service with three customers in the summer and fall.
- Providing fungal solutions for cultivated meat structure.
    - Novel Farms formed to add biocompatible domains to fungi to create better scaffolds for structured cultured meat products.

Are we missing something? Did we get something wrong? We'd appreciate your feedback via **this form**.

Investments

Image credit: Impossible Foods

Section 4: Investments

Overview

Fermentation has rapidly become a robust part of the alternative protein investment landscape. In 2020, fermentation companies raised $587 million, a twofold increase from 2019 that accounted for 19 percent of overall funding in the alternative protein sector and represents 57 percent of all-time funding for fermentation companies.

The fermentation segment further matured and diversified in 2020:

- Perfect Day extended their Series C funding round to $300 million.
- MycoTechnology **won a $1 million nondilutive prize in Syngenta's Radicle Protein Challenge**.
- In addition to an $80 million Series B round in March, Nature's Fynd closed a **$45 million venture debt round** in December.
- Air Protein, Meati Foods, Prime Roots, Remilk, Solar Foods, The Protein Brewery, and Mushlabs all raised Series A rounds of $10 million or higher. These seven rounds represent a 75 percent increase in number of Series A rounds from 2019.

While 2020 was a record year for fermentation investment, significant additional investments from public and private funders are needed to support R&D innovation, accelerate the derisking and commercialization of promising technologies, and scale up production capacity. Of particular need are nondilutive investment methods, such as debt financing, grants, guarantees, purchase commitments, equipment and facility leasing, and other financing vehicles tailored to infrastructure and R&D expansion. Another undersupported area is contract capacity, a critical need for fermentation startups looking to scale rapidly.

For more information on fermentation investment white spaces and ideas for solutions, please view GFI's **Advancing Solutions** webpage.

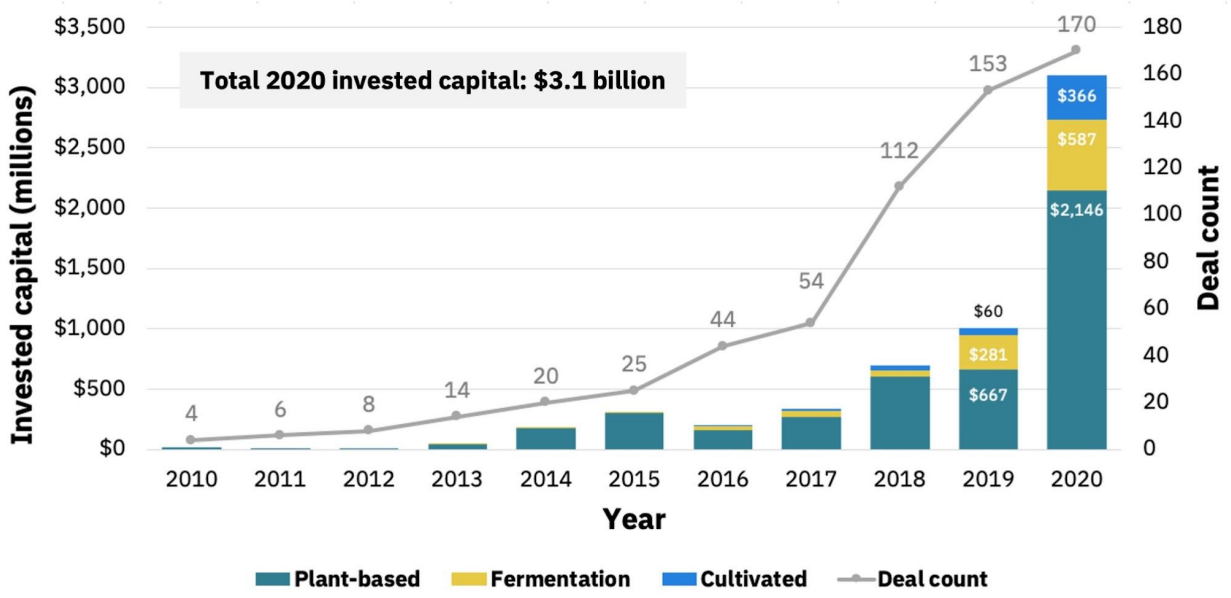
Table 3: 2020 investment overview

Total invested capital	Largest investment	Unique investors
$587 million (57% of all-time investment, up 109% from 2019) **$1 billion** (2013–2020)	**$300 million** (Perfect Day)	**80** new (up 45% from 2019) **259** total (2013–2020)
Series A/A1/A2 fundraising rounds	**Series B fundraising rounds**	**Series C/C1 fundraising rounds**
7 new **19** total (2015–2020)	**1** new **3** total (2017–2020)	**1** new **3** total (2017–2020)
Invested capital deals		**Liquidity events**
28 new **102** total (2013–2020)		**0** new **$1.49 billion** total (Quorn, 2003–2017)

Source: GFI analysis of PitchBook data.
Note: Data has not been reviewed by PitchBook analysts. Total invested capital includes deals with undisclosed dates and thus may not match the sum of annual invested capital figures in this report.
See Box 2 for GFI's data collection methodology and definitions of "invested capital" and "liquidity events."

PitchBook

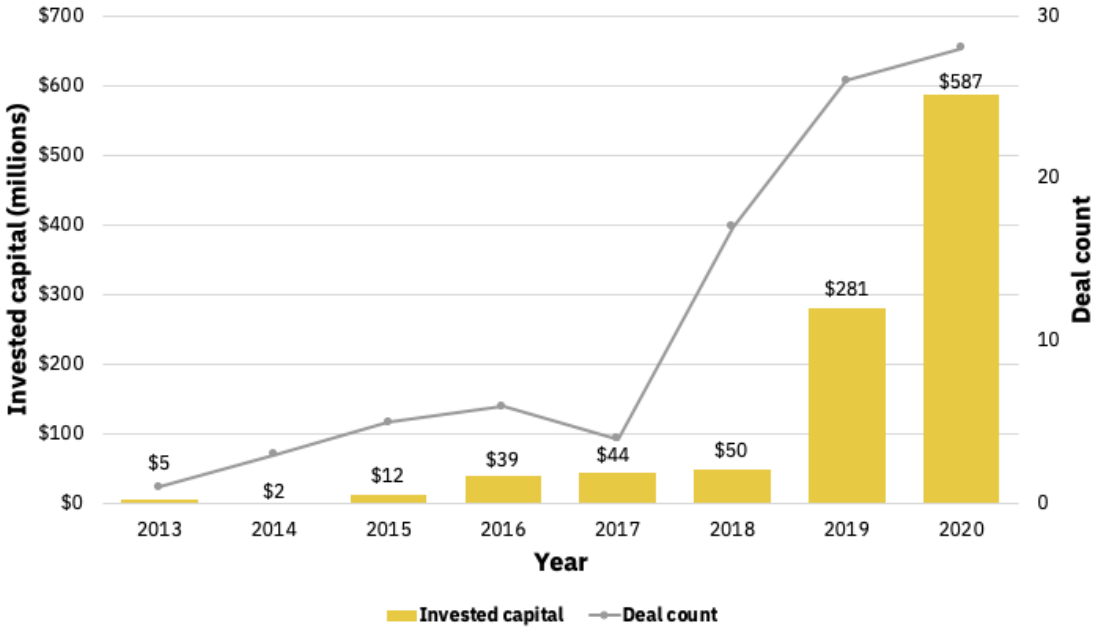
Figure 7: Annual alternative protein investment backdrop (2010–2020)



Source: GFI analysis of PitchBook data.
Note: Data has not been reviewed by PitchBook analysts.

PitchBook

Figure 8: Annual investment in fermentation companies (2013–2020)



Source: GFI analysis of PitchBook data.
Note: Data has not been reviewed by PitchBook analysts.

PitchBook

Box 2: Data collection methodology

GFI conducted an analysis of fermentation companies worldwide using data from PitchBook. Our analysis uses a list we custom built in PitchBook of companies focused primarily on fermentation-enabled meat, egg, or dairy products or providing services to those who produce them. Our analysis excludes the many companies involved in fermentation but not as their core business (Figure 5) and companies using fermentation other than to create or enable alternative meat, egg, and dairy products. PitchBook profiled 44 fermentation companies, of which 34 have disclosed deals. Of these 34 companies, 32 have deals with publicly disclosed amounts. Because these aggregate calculations include only companies with deals and deal sizes disclosed to PitchBook, they are conservative estimates. For example, $1 billion total invested capital raised excludes 27 deals (from a total of 102) with undisclosed or unavailable amounts. This means at least 26 percent of deals in this industry are not represented.

For the purposes of this report, *invested capital / investment* comprises accelerator and incubator funding, angel funding, seed funding, equity and product crowdfunding, early-stage venture capital, late-stage venture capital, private equity growth/expansion, capitalization, corporate venture, joint venture, convertible debt, and general debt completed deals. *Liquidity events* comprises mergers, acquisitions, reverse mergers, buyouts, leveraged buyouts, and IPOs, while *other financing* comprises subsequent public share offerings and private investment in public equity. We do not include capital raised through a SPAC IPO until the entity has merged with or acquired a target company. Please note that the figures published in this report may differ from prior figures published by GFI as we continually improve our dataset.

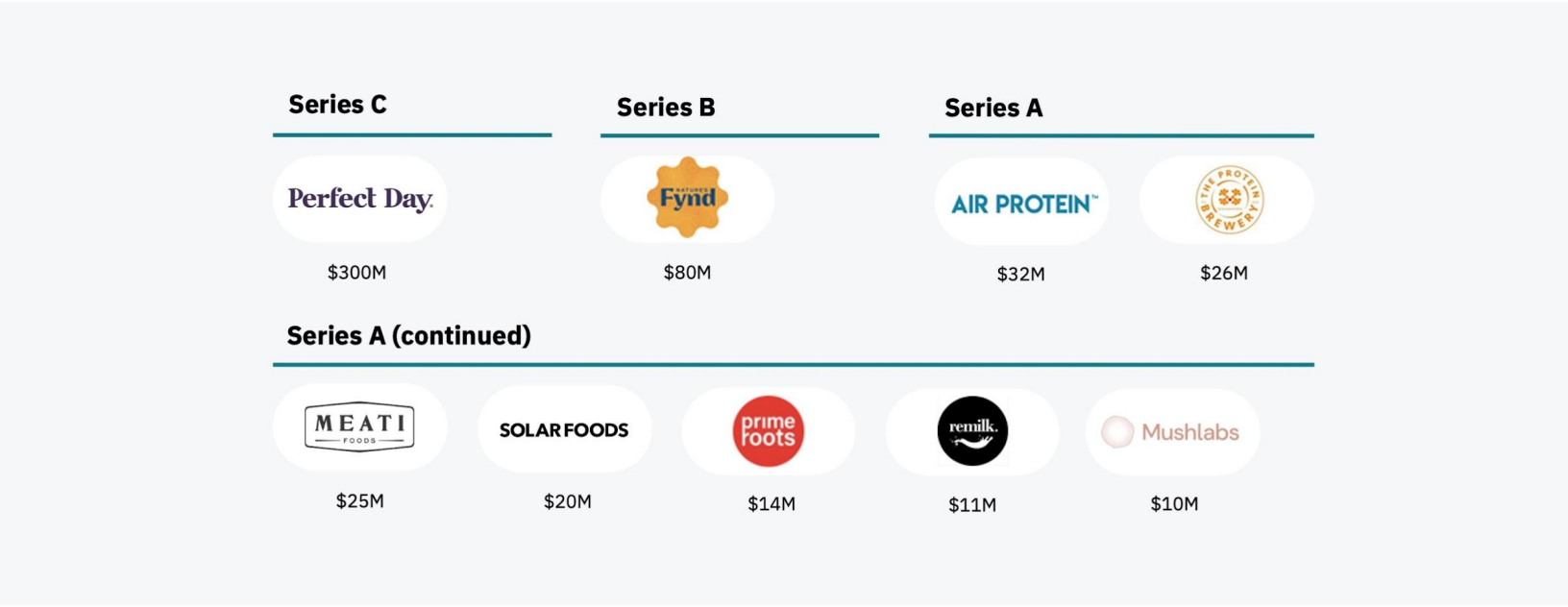
Table 4: Deal type summary statistics (2013–2020)

Deal type	Median	Minimum	Maximum	Count
Seed	$2M	$1M	$7M	21
Series A/A1/A2	$14M	$3M	$90M	19
Series B	$42M	$40M	$80M	3
Series C/C1	$23M	$7M	$300M	3

Source: GFI analysis of PitchBook data.

Note: Data has not been reviewed by PitchBook analysts. These figures represent summary statistics of invested capital rounds with disclosed deal amounts. Deal count includes rounds with undisclosed amounts. Due to their limited number and size, this table excludes angel, corporate, and Series 1 rounds. It also excludes uncategorized rounds.

Figure 9: 2020 key funding rounds



Source: GFI analysis of PitchBook data. Data has not been reviewed by PitchBook analysts.

Box 3: A case study in liquidity events

The alternative protein fermentation sector is too young for us to expect many liquidity events, such as IPOs or acquisitions that drive the venture capital investment model. However, Quorn, the mycoprotein pioneer founded decades before most other mycoprotein companies, provides a promising case study. Rank Hovis McDougall (RHM), a UK-based food company, began research and the regulatory approval process for their products in the 1960s. But not until 1985 was the brand Quorn (named after a British village) first marketed via a joint venture between RHM and Imperial Chemical Industries (ICI).

Quorn first sold at Sainsbury's in the United Kingdom in the form of savory pies. Other parts of Europe followed and finally North America in 2002. As one of the first alternative protein market entrants, Quorn enjoyed market dominance and commercial success. In 1993, Quorn was spun off by ICI, which had acquired all of RHM's shares, to AstraZeneca. In 2003, Montagu Private Equity bought Quorn for $116 million before selling it two years later to Premier Foods for $315 million. In 2011, other private equity investors acquired Quorn before Monde Nissin, a Philippines-based food company, ultimately acquired it for $726 million in 2017. Notably, Quorn has also successfully secured large tranches of debt financing, including a $147 million debt refinancing, a 113 million GBP note, and a 10 million GBP revolving credit line from CitiGroup Global Markets and HSBC Bank in March 2019 per PitchBook. We expect other fermentation companies to experience liquidity events within years, not decades.

Table 5: Most active investors in 2020

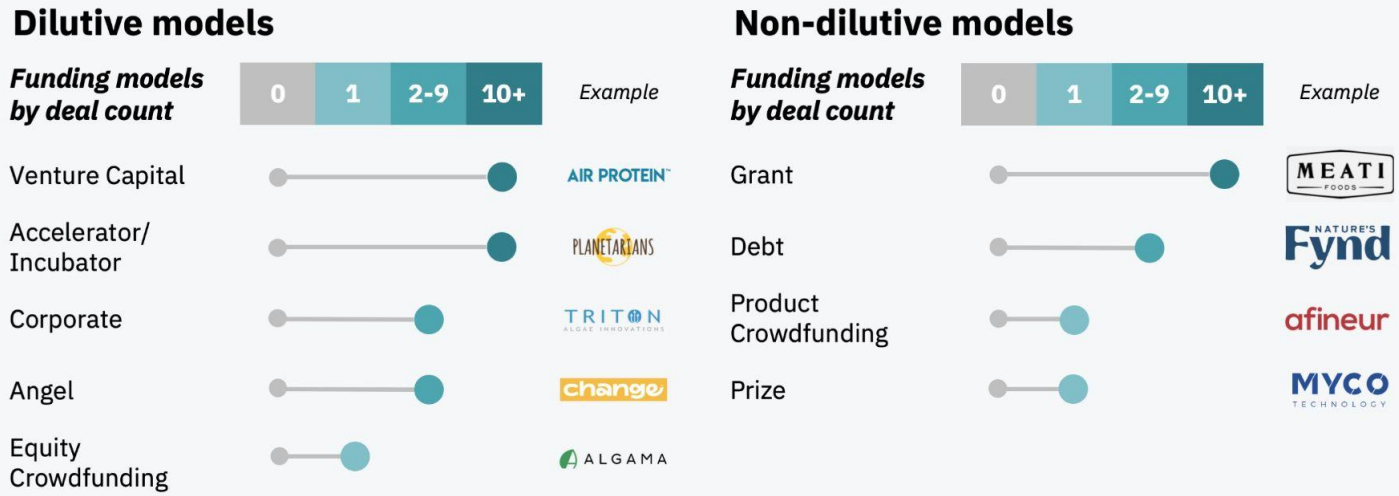
Investor	Investor type	Headquarters	2020 deal count	Portfolio companies (number of investment rounds participated in)
CPT Capital	Venture capital	London, United Kingdom	3	Motif FoodWorks (1) 3F Bio (1) Better Dairy (1) Clara Foods (1) Formo (1) New Culture (1) Perfect Day (1) Remilk (1) Solar Foods (1)
SOSV / IndieBio	Venture capital	Princeton, NJ, USA	3	New Culture (3) Planetarians (3) Prime Roots (3) Clara Foods (2) Perfect Day (1)
ADM Ventures	Corporate venture capital	Lugano, Switzerland	2	Nature's Fynd (2) Air Protein (1) Perfect Day (1)
Happiness Capital	Corporate venture capital	Hong Kong, SAR, China	2	Mushlabs (2) Better Dairy (1) Formo (1)
ProVeg Incubator	Accelerator/incubator	Berlin, Germany	2	Remilk (2) Formo (1) Mushlabs (1)
Temasek Holdings	Sovereign wealth fund	Singapore	2	Perfect Day (3) Sophie's Bionutrients (1)
Social Starts	Venture capital	San Francisco, CA, USA	2	Meati Foods (2) Mushlabs (1)
Stray Dog Capital	Venture capital	Leawood, KS, USA	2	Atlast Foods (1) Better Dairy (1) Wild Earth (1)
Unovis Asset Management	Venture capital	New York, NY, USA	2	Atlast Foods (1) Meati Foods (1) The Protein Brewery (1)
Kishore Ganji*	Angel (individual)		2	Helaina (1) New Culture (1)
Maya Hari*	Angel (individual)		2	Change Foods (2)
Michal Klar*	Angel (individual)		2	Change Foods (2)

Simon Newstead*	Angel (individual)	2	Change Foods (2)
Tom Crago*	Angel (individual)	2	Change Foods (2)

**Indicates funders that made disclosed investments in fermentation-enabled meat, eggs, and dairy for the first time in 2020.*

Source: GFI analysis of PitchBook data. Data has not been reviewed by PitchBook analysts. "Most active investors" includes those who made two or more investments during the calendar year.

Figure 10: Funding models by deal count



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Science and technology

Image credit: Motif FoodWorks

Section 5: Science and technology

Despite microbial fermentation's long history in food and industrial biotechnology, tremendous potential for innovation remains. The vast biological diversity of microbial species, coupled with virtually limitless capabilities in biological synthesis, translates to massive opportunities for novel alternative protein solutions to emerge from fermentation-based approaches. Opportunities to advance fermentation can be segmented into five key areas spanning the value chain: target selection and design, strain development, feedstock optimization, bioprocess design, and end-product formulation and manufacturing.

For a comprehensive view of the state of the science in fermentation-enabled meat, eggs, and dairy—including a deep dive into each component of the value chain—check out GFI's **science of fermentation** page.

Key areas for science and technology development

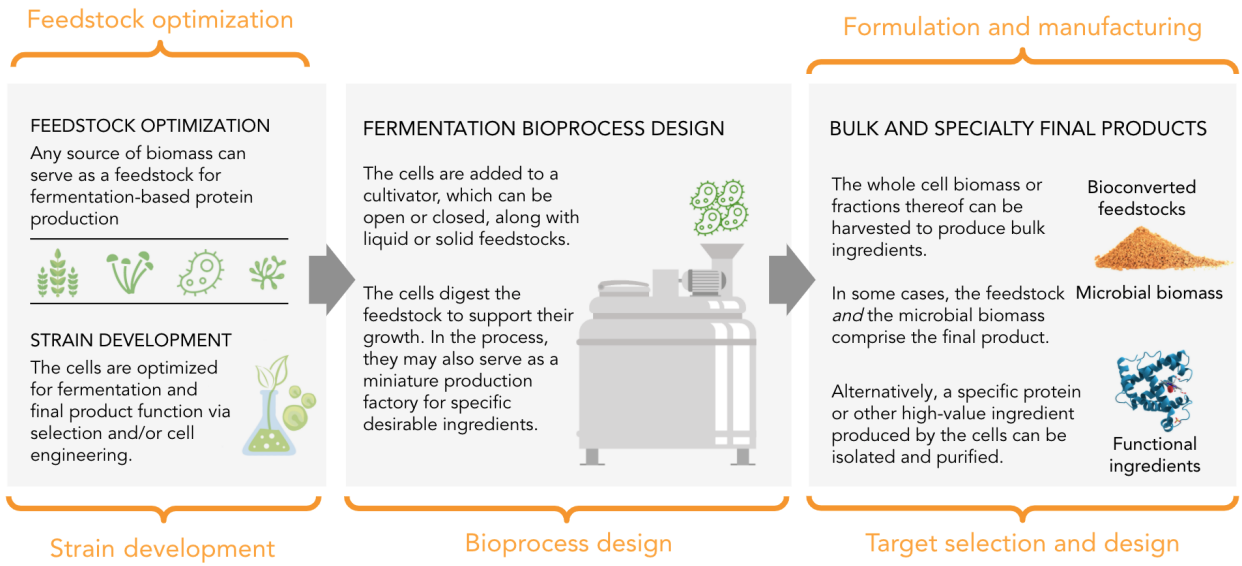
In 2020, GFI launched the **Advancing Solutions** repository of solutions and innovation priorities for alternative proteins, providing analysis on opportunities and challenges in fermentation. Our menu of alternative protein insights and opportunities for businesses, investors, nonprofits, academic researchers, and governments is based on interviews with more than 150 experts throughout the alternative protein value chain, including scientists, investors, entrepreneurs, and consultants.

Identified below are the key innovation priorities for fermentation-powered alternative proteins:

- Increased titers and yields of target molecules and protein biomass.
- Strain engineering to allow for the use of less expensive feedstocks.
- Safety studies and genetic tools for more microbes to enable more innovation by expanding the selection of host strains.
- Bioreactor innovation to create equipment that is optimized for food-grade fermentation.
- Downstream processing innovation, such as cell harvesting and target molecule purification, which must become less costly and easier to scale, as capacity is a major bottleneck.
- Characterization and analytical tools for inputs, as current methods are resource-intensive and slow.
- Co-product valorization using side streams from traditional crop harvesting and processing fractions and upcycling spent media and other co-products from fermentation processes.
- Feedstock consistency and cost reduction. Shipping costs are currently high unless production is co-located with feedstock sources, which raises concerns about food

safety and regulation around inputs such as agricultural side streams. Meanwhile alternative feedstocks remain highly inconsistent.
- Alternative substrates that are less expensive, more sustainable, and widely available in order to reach mass commercialization.

Figure 11: A visual overview of the technology value chain for fermentation



Source: GFI.

Below are some of the most needed solutions that emerged during the Advancing Solutions surveys:

- **Comprehensive microbial screening to identify new protein-production candidate strains.**
- **Biosynthetic pathway discovery for fermentation-produced molecules.**
- **Producing animal-like fats through microbial fermentation.**
- **Fat production and encapsulation within oleaginous yeast.**
- **Biological and enzymatic processing methods for plant proteins.**

2020 also saw significant research and development updates:

- TurtleTree Labs **spun out TurtleTree Scientific** and partnered with a major filamentous fungi company to produce growth factors. Although announced in 2021, the partnership developed in 2020.
- The search for suitable microbial strains broadened to include the anaerobic realm, which opens the door to repurposing large-scale ethanol production infrastructure that is not suitable for aerobic fermentation. White Dog Labs (Superbrewed Food) purchased an ethanol plant with **plans to convert it** for aquaculture feed production.
- Quorn **opened the new Fermentation Development Centre** to accelerate their protein research.

- 3F Bio **opened a pilot-scale facility** to generate operational data to support their commercial scaleup and advance their fundamental bench-scale R&D work.

To dig deeper into the most pressing challenges and greatest white spaces in fermentation-enabled alternative proteins, check out GFI's Advancing Solutions insights:

- Innovation priorities. Overview of commercial white spaces, research gaps, technological needs, and investment priorities at each stage of the value chain.
- Solutions database. Frequently updated database of ideas for new startups, commercial ventures and products, research projects, ecosystem support, and investment opportunities.

Box 4: Prospects for scaling and cost reduction

Traditional and biomass fermentation processes offer well-established examples of scalability and cost reduction suitable for alternative protein applications. Further innovation to reduce costs is certainly possible for these platforms and will be important for widespread deployment in low- and middle-income countries, but precedent for economic viability and true industrial scale already exists. However, precision fermentation will require additional scaling and cost reduction to manifest its potential in the alternative protein industry. Some applications of precision fermentation in this industry are already profitable, but others pose cost challenges.

Which price points are achievable for products of precision fermentation, and how quickly? The answer depends on multiple factors, but there is reason to believe that products created via precision fermentation can achieve price parity with comparable conventional animal products through a combination of approaches:

1) Increasing scale. Economies of scale dictate that costs decrease as scale increases up to an asymptote where the marginal production cost is equal to the cost of the inputs.
2) Improving volumetric productivity. Volumetric productivity is the amount of desired product that can be produced in a given volume in a given period, and increasing this will improve capital utilization and lower unit costs.

3) Prolonging continuous bioprocessing. Because of the power of exponential growth within cell culture platforms, fermentation processes operate most efficiently and productively at their peak volume and density.
4) Decreasing inclusion levels in final products. Alternative protein products benefit from highly functional fermentation-enabled ingredients, even at low inclusion levels. Developing ingredients that impart the desired functionality at lower volumes will enable companies to create end products at higher volumes and lower prices.
5) Relaxing purification stringency. Many applications of functional proteins in food may not require the same level of purity as active proteins, such as enzymes. Purification composes a substantial fraction of the overall production cost for many recombinant proteins, so relaxing purification requirements will significantly reduce cost.

See more insights.

"Consumers are driving the demand for nonanimal sources of protein. Food brands will naturally respond to meet consumer needs but can only do so with a ready supply of high-quality ingredients. The benefits of both biomass and precision fermentation unlock the opportunity to make better products and to do so at a scale to replace the animal using regionally grown, sustainable ingredients."

—Jim Laird, CEO of 3F Bio

Box 5: From the tank to the field: Plants as an expression platform

While most recombinant protein production uses precision fermentation in microbial hosts, crop plants can also serve as hosts for production of high-value target molecules. Plants engineered to produce ingredients of interest can be grown and harvested inexpensively and at large scale through traditional agricultural systems, which may require less infrastructure and therefore less capital expense than fermentation systems. Upon harvest, downstream purification proceeds much as it would if the host were microbial. Introduction of high-value ingredients into edible plants also opens the door to less-intensive downstream purification if the crop itself can be used as an ingredient with built-in enhanced functionality.

Target molecules for expression in plants might include heme proteins or growth factors for cultivated meat production, such as those pursued by Core Biogenesis and ORF Genetics. At least 11 publicly announced companies are now working on this approach, including Tiamat Sciences, Alpine Roads, Mozza, ORF, Core Biogenesis, Moolec Science, Greenovation Protein, Fantastic Farms, BioBetter, InVitria, and Genius Foods. This expression platform will continue to shift both cost and production paradigms and unlock further innovation in recombinant proteins.

Ramen with mycelium-based steak from Meati Foods. | Image credit: Meati Foods

GFI's research grant program

While GFI's competitive research grant program has historically focused on plant-based and cultivated protein technologies, our 2021 request for proposals includes microbial fermentation as a third eligible technological platform. GFI also supports white space collaborations and provides small-scale exploratory grants for research in fermentation-enabled alternative protein, in addition to aggregating a **database of third-party research funding opportunities** that are relevant to alternative proteins.

Fermenting oat proteins

Research highlight: Mari-Liis Tammik, research scientist at TFTAK (Center of Food and Fermentation Technologies) in Estonia, led a project **exploring fermented oat protein** for use in plant-based meat. Oat protein has an excellent amino acid profile and low allergenicity, and this work enables further research on fermentation of a wide variety of cereal grains to improve their nutritional profiles and sensory attributes. Specifically, fermented oats are used in this project as a novel constituent in plant-based meat. The research began with identifying starter cultures to improve nutritional and organoleptic properties of oat protein. It then developed oat-based meat for comparison with conventional meat and other non-oat plant-based meat.

Fermenting flavor bases

Research highlight: BZ Goldberg, CEO and R&D director at The Mediterranean Food Lab in Israel, is leading a project to explore **the potential of traditional and adapted multiphase fermentation technologies** to develop new meat flavors from plant ingredients. These flavors can be added to plant-based meat products. The research develops production protocols for elevating and accentuating beneficial organoleptic factors in flavor-rich ingredients. This work will enable plant-based ingredients to emulate the flavor profile of conventional meat. It will help expand the types of plant-based ingredients that address critical culinary functions of animal-based meat and other animal proteins. In November, The Mediterranean Food Lab **became one of three winners of the EIT Food Accelerator Network** program.

Check out our **research grants** page to explore grant opportunities (at GFI and elsewhere!) and meet the scientists leading open-access fermentation research for applications in meat, eggs, and dairy.

Government and regulation

Image credit: Air Protein

Section 6: Government and regulation

Regulatory updates

Both microbial fermentation as a processing method and ingredients derived from microbial cultures have a long history of use in the food industry—precision fermentation to create the rennet used in most animal-based cheese products, for example. Given this history, well-established regulatory systems to ensure the safety of innovations in this platform are already in place in most jurisdictions. However, each regulatory agency and framework presents its own nuances and idiosyncrasies.

In November, the Singapore Food Agency (SFA) updated a year-old **guidance document** on novel-food safety assessments. The guidance provides little new detail as to which standards manufacturers must satisfy to obtain approval of their products. As it stands, the SFA strongly encourages companies interested in selling alternative protein products in Singapore to contact the regulatory body early in the R&D and commercialization planning process. According to the SFA, the framework set forth in the guidance document steered the SFA's approval of **Impossible's soy leghemoglobin in August** and **Triton Algae's Chlamydomonas reinhardtii algae** in November 2019.

Multiple companies have already obtained "no questions" letters from the FDA for purified fermentation-derived ingredients, meaning the FDA does not object to the companies' view that their ingredients are "**generally recognized as safe**" (GRAS).

- Nature's Fynd (formerly Sustainable Bioproducts) filed a **GRAS notice** with the FDA in January 2020; the FDA's response is pending.
- In March 2020, Perfect Day received a **no questions letter** from the FDA in response to their GRAS notice for beta-lactoglobulin, the major protein in whey.

In December 2020, Impossible Foods received **approval** for their heme from the regulatory agency Food Standards Australia New Zealand; the approval became final in February 2021, opening up another large market.

Box 6: Trade association facilitating regulation negotiation in Brazil

GFI Brazil, along with 29 companies in the alternative protein market (products, ingredients, and investors), launched a trade association in late 2020 to help

facilitate negotiations between the industry and the government. In December 2020, the Brazilian Ministry of Agriculture hosted a workshop to discuss a new regulatory framework for alternative proteins, including plant-based and fermentation-enabled proteins. GFI Brazil helped organize the event and supplied presenters. The workshop attracted more than 300 attendees and vast media coverage.

The Brazilian Ministry of Agriculture hosted a workshop on alternative protein regulatory frameworks in December 2020. Panelists included (clockwise from top left) Hugo Caruso from DIPOV/MAPA (Division of Vegetable Products of the Ministry of Agriculture), Alexandre Novachi from ABIA (Brazilian Food Industry Association), Gus Guadagnini, managing director of GFI Brazil, Dr. Caroline Mellinger from Embrapa (Brazilian Agricultural Research Corporation), and Igor Castro from ABIR (Brazilian Association of Refrigerated Drinks) | Image source: GFI Brazil.

Labeling and nomenclature

Labeling of fermentation-enabled and plant-based products remains contentious in some markets. In October 2020, the European Parliament **rejected** a bill that would have prohibited the use of meat terminology like “sausage” or “burger” on labels for products not derived from an animal carcass. The Parliament did, however, pass a similar ban which introduced further restrictions on the labelling of plant-based dairy. While dairy terms such as “milk” and “yoghurt” are already banned under EU law, these new restrictions would ban any ”evocation” of the concept of dairy, even when used with a clear modifier such as “alternative” or “style.” EU member states and the European Parliament are still negotiating whether this ban is going to become law.

Outside governmental prescription, the advanced fermentation sector—companies producing animal-free dairy, eggs, and other novel proteins—has not yet aligned on standard terminology for products or ingredients derived from precision fermentation, although there is an acknowledged need for nomenclature studies. Several leading companies in the precision fermentation sector are working together to identify appropriate nomenclature. Currently, several distinct terms are in use:

For ingredients:

- The ingredients disclosure on labels for **Smitten ice cream**, which is made with ingredients from Perfect Day, uses "non-animal whey protein isolate." This parallels "non-animal rennet," a widely accepted term used by cheese manufacturers to refer to rennet made via precision fermentation. Smitten's packaging also includes a dairy allergy warning.
- **Perfect Day** uses the term "**microflora**" for the microbial hosts and "flora-derived protein" for the animal-free dairy proteins in marketing materials. Unlike probiotic products that also use the term "flora," Perfect Day's products do not contain live cultures.
- **Clara Foods**, a food technology company making eggs and other animal-based proteins using precision fermentation, plans to describe their products as "animal-free."

For products:

- **Brave Robot**, which also uses ingredients from Perfect Day, describes their ice cream as "animal-free dairy."
- **Change Foods**, a company making dairy products enabled by precision fermentation, also describes their products as "animal-free dairy."

In the biomass fermentation sector, companies are using various terms to describe products and ingredients:

- **Quorn** coined the term "**mycoprotein**" to describe their fungal-derived protein ingredient, but another term may work equally well or better for this type of biomass. Note that as a **settlement** term of a **class action suit**, the company has since modified their packaging in the United States. The allergen warning now reads: "Mycoprotein is a mold (member of the fungi family). There have been rare cases of allergic reactions to products that contain mycoprotein" (even though fungal food allergies are much less common than soy allergies).
- **MycoTechnology** and other companies that use mycelium from species such as *Lentinula edodes*, whose fruiting bodies are consumed as shiitake mushrooms, may be able to use "mushroom protein," "mushroom extract," or similar terms.

Government support

Fermentation is a paradigm-changing innovation. It can unlock new high-value uses for low-value agro-industrial byproducts, affordably nourish the world's growing population, and help ensure protein sovereignty and security (unlike slaughterhouse closures during a pandemic). Thus, it is not surprising that some governments have taken an active hand in supporting companies in the space.

The United States, the European Union, Israel, and Singapore are among the first governments to provide support for the sector. 2020 brought several developments:

- Meati Foods (formerly Emergy Foods) received an equity investment from the U.S. Department of Energy via the **incubator arm** of Argonne National Laboratory.
- Mycorena received a 50,000-euro grant from the European Commission, the executive branch of the European Union, to help fast-track their product to market.
- 3F Bio, alongside a consortium of other companies, received a 17-million-euro grant from the EU Horizon 2020 program to develop a zero-waste biorefinery to produce food-grade protein from low-cost, sustainable feedstocks. The project, called **PLENITUDE**, brings together 3F Bio, a bioethanol biorefinery, Bridge2Food, Mosa Meat (a cultivated meat company), Wageningen University, International Flavors & Fragrances, Alcogroup SA, and others.
- EIT Food Accelerator Network (funded by a European Commission Horizon 2020 grant) announced their 2020 **cohort**, which included Mycorena and The Mediterranean Food Lab, as well as several cultivated meat and plant-based meat, egg, and dairy companies.
- San Francisco's Perfect Day **announced** that they would collaborate with Singapore's Agency of Science, Technology and Research (A*STAR) to build a research and development center.
- **The EU Smart Protein project published a new fermentation-related research study** led by University College Cork. The project is a $10.5 million initiative of the European Union to **support the alternative protein industry** and includes support for fermentation (fungi and side-stream conversion).

Nacho cheese sauce from Perfect Day. | Image credit: Perfect Day

Conclusion and forecast

Image credit: Triton Algae Innovations

Section 7: Conclusion and forecast

2020 was a landmark year for fermentation, which emerged as a pillar of the alternative protein industry. Alongside plant-based proteins and cultivated meat, fermentation will help us sustainably feed a global population of nearly **10 billion** by 2050. Because of its vast potential in technical and product development innovation, fermentation is well positioned to exceed the sensory, nutritional, environmental, social, market, and functional paradigms of status quo proteins in today's food system.

Fermentation is not just valuable in its own right, offering competitive prices, unparalleled functionality and scalability, and validated mechanisms for establishing and ensuring safety; it also stands to revolutionize the entire alternative protein industry, with spillover applications in plant-based products and cultivated meat. Fermentation can enable a new generation of proteins, fats, and other functional ingredients that combine with plant-based and cultivated components to create biomimicking whole-cut meats, egg replacements, animal-free dairy proteins, seafood products, and more.

The alternative protein industry has barely scratched the surface of the potential for fermentation-based approaches, and both consumers and existing players in the sector are eager for the innovative products and solutions that fermentation can provide. GFI looks forward to supporting the innovators in this sector as they drive the transformation of our food system into one that is more sustainable, secure, and just.

Doris Lee, general manager of GFI Consultancy, speaks at the first fermentation and cultivated meat conference in China.

Forecast

Broader commercialization

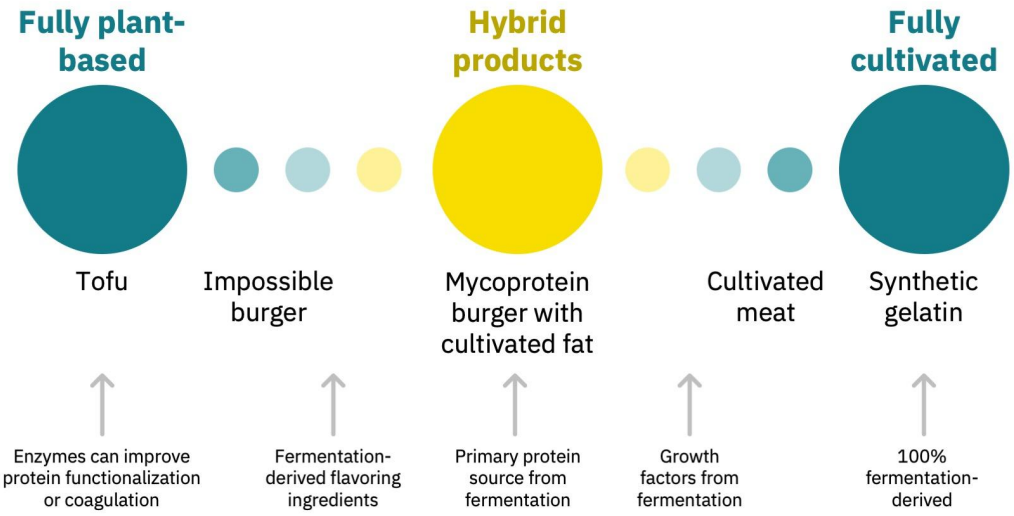
We expect 2021 to be another unprecedented year of research and development breakthroughs in fermentation, fueled by a record-setting amount of industry fundraising. Fermentation-enabled alternative proteins are entering the proof of concept stage, with pioneering products starting to reach customers. Early adopters will provide evidence of product-market fit and help producers refine their product formulations, marketing mixes, and distribution strategies.

Global changemakers are taking notice; Bill Gates noted that alternative protein innovation will be a core part of fighting climate change in an **appearance on CBS News' *60 Minutes*** in February 2021. In addition to mentioning several plant-based meat manufacturers, Gates singled out Nature's Fynd as a company doing earth-saving innovation. Gates is an investor in Nature's Fynd and other alternative protein companies because he believes in their climate mitigation potential.

Hybrid products

We also anticipate that hybrid products containing multiple types of protein will play an increasingly significant role in alternative protein product launches. We have already seen activity in this area; Back of the Yard Algae Sciences **announced** a microalgal heme ingredient for plant-based meat in early 2021, potentially enabling other companies to unlock the "bloodiness" that the Impossible Burger pioneered. Over the next few years, many products will not rely solely on fermentation-derived proteins but will include plant and animal cell components, just as Impossible Foods' beef derives from a mixture of plant and microbial sources, with the fermentation-derived ingredients providing significant sensory benefits. Companies operating at the intersection of the three alternative protein categories will enable a new wave of paradigm-shifting meat, egg, and dairy products and ingredients that meet consumer expectations for taste, price, functionality, versatility, and variety.

Figure 12: A spectrum of hybrid fermentation-enabled products



Scaling and expansion

As these products enter the market and demonstrate consumer traction, industry activity is likely to accelerate. The substantial cash inflows in 2020 will fuel capital expenditures for production facilities and expand the size of skilled science and engineering teams, enabling industrial bioprocesses to grow in scale, companies to develop new products, feedstocks to diversify, and more companies to emerge. All this activity will improve the end products' quality and price, driving further adoption.

Geographical diversification

Historically, the United States and Europe have served as major innovation hubs for industrial biotechnology and fermentation, particularly from a technology development standpoint. Lately, Asia and Latin America have increasingly positioned themselves as leaders in manufacturing capacity and fermentation infrastructure. With the advent of new research tools that decrease the cost of R&D, innovation is likely to come increasingly from regions that have not traditionally led biotechnology developments. These regions will be able to couple upstream strain and feedstock improvements with the operational expertise required for swift integration into large-scale manufacturing environments, potentially accelerating the iterative innovation cycle and path toward cost reduction. Governmental investment is an "X factor" that could rapidly accelerate industry growth as we have seen with Israel and Singapore.

Expert predictions

Looking to the year ahead, we asked a group of industry experts for their predictions of what's next in fermentation for alternative proteins.

The whole space for fermentation and alternative proteins is about to break wide open. We're on the cusp of seeing more possibilities emerge than ever before when it comes to improving taste and nutrition. That means the benefits for CPG companies and consumers in the plant-based food space will begin to materialize at a faster and faster pace. The companies that can keep up with this pace—and that have the scientific skill along with access to a broad range of strains and proteins to create these benefits—will come out on top.
—Michael Leonard, Motif FoodWorks

I believe fermentation will take center stage not just when it comes to alternatives to meat, but also for food ingredients and products beyond protein. Functional ingredients, nutrients mainly derived from animals, and old fermentation products with new applications (e.g., enzymes) will find their way into our everyday foods.
—Abril Estrada, Wild Earth

We will see better products as a wider number of brands increase the pace of innovation. To underpin this, it is essential that we see an increase in supply capacity. If we believe in the projection of 25%–30% CAGR, then for fermentation to even maintain its share of the market, there is a need for a 10x+ increase in capacity by 2030. We will also see governments increase their level of investment in non-animal protein sources. This will accelerate trends such as the Spanish government's investment in Ethicameat, Singapore's "30 by 30 vision," and the EU's commitment to bio-based industries.
—Jim Laird, 3F Bio

The forecasted demand for alternative proteins requires significantly more fermentation capacity than exists today, representing a state-of-readiness bottleneck. While this has the potential to prompt large companies and governmental entities to fund expanded capacity, identification and emphasis on the shortfall is critical to prompting the required action.
—Mark Warner, Warner Advisors

Solid-state fermentation will emerge as a new modality to create structured proteins and whole cuts of meat analogs that are not possible through liquid fermentation.
—Eben Bayer, CEO of Ecovative and Atlast Food Co.

Acknowledgments

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Cover image courtesy of Atlast Food Co.

About GFI

GFI is a 501(c)3 nonprofit organization developing the roadmap for a sustainable, secure, and just protein supply. We identify the most effective solutions, mobilize resources and talent, and empower partners across the food system to make alternative proteins accessible, affordable, and delicious.

Our vision:
A world where alternative proteins are no longer alternative.

Our programmatic priorities:

- **Science and technology:** Advancing foundational, open-access research in alternative proteins and creating a thriving research and training ecosystem around these game-changing fields.
- **Corporate engagement:** Partnering with companies and investors around the globe to drive investment, accelerate innovation, and scale the supply chain—all faster than market forces alone would allow.
- **Policy:** Advocating fair policy and public research funding for alternative proteins.

Alternative proteins are a global solution to global problems. In addition to the United States, GFI works in places where we can have the greatest possible impact on our global food system: Asia Pacific, Brazil, Europe, India, and Israel.

GFI is 100 percent powered by philanthropy. Our progress is possible thanks to gifts and grants from our global family of donors.

People around the world support our work because, together, we can transform our food system to mitigate climate change and environmental degradation, feed our planet's growing population, and secure a food supply that decreases the risk of zoonotic and antibiotic-resistant diseases.

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