ACTION PAPER
Last update: August 2026

Unlocking the environmental benefits of fermentation-derived food ingredients: Policy recommendations

Fermentation-derived food ingredients represent a near-term, commercially ready opportunity to substantially reduce the environmental footprint of protein and oil supply chains. Policymakers should invest in fermentation-derived proteins for a secure, sustainable food supply. Beyond their significant environmental benefits, alternative proteins expand consumer choice and promote national security by increasing supply chain resilience (ETI and GFI, 2026).

Overview

Fermentation-derived ingredient production is a promising platform for sustainable food production. As protein consumption increases worldwide, fermentation-derived protein represents an efficient, nutritious, and scalable solution to decrease environmental impacts associated with animal-sourced foods. Governments can unlock further innovation in the sector and accelerate production with targeted policy actions. Policies to support commercialization, including loans, loan guarantees, and manufacturing grants, can de-risk and attract private capital to support scale-up.

What are fermentation-derived food ingredients?

Fermentation is a process in which microorganisms—bacteria, fungi, and yeasts—convert carbon sources into proteins, oils, and other useful compounds. The food industry is now applying more advanced fermentation processes to produce sustainable alternative proteins, fats, and food ingredients from microbes and diverse feedstocks.

ÄIO's Encapsulated Oil made via fermentation. Photo credit: Aivo Kallas

Three distinct pathways produce these ingredients:

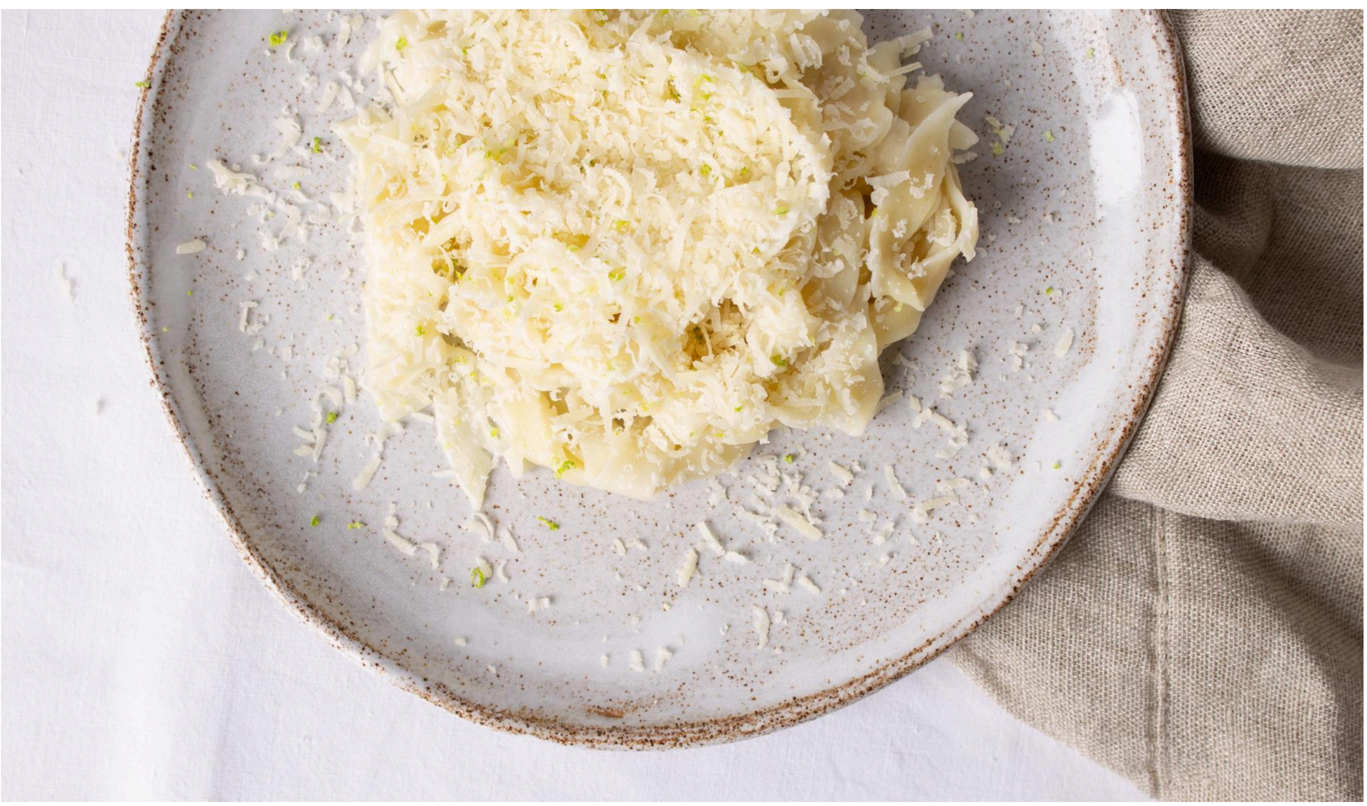
Biomass fermentation, also known as single-cell protein (SCP), leverages the high-protein content and rapid growth of microorganisms to produce large quantities of protein efficiently—without raising animals. Mycoprotein, produced from filamentous fungi such as *Fusarium venenatum*, is the most commercially established example, with decades of production and consumption experience.

Precision fermentation uses microorganisms as biological factories to produce specific functional proteins and other molecules—including whey protein, egg white protein, casein, heme, and collagen—that are nutritionally and functionally equivalent to their animal-derived counterparts. Unlike biomass fermentation, the microorganism itself is not the end product; instead, it produces a target ingredient that is then purified.

Microbial oils are fat ingredients produced by oleaginous yeasts and microalgae—organisms that naturally accumulate high levels of lipids—and can serve as land-based replacements for omega-3 fish oils extracted from ocean fisheries, including DHA and EPA omega-3s.

What does the evidence show?

A systematic review of LCA evidence conducted by the Good Food Institute, synthesizing findings from over 30 peer-reviewed and industry publications, found that fermentation-derived ingredients have a substantially lower environmental footprint than conventional animal-based ingredients. Environmental advantages—including lower greenhouse gas emissions, land use, and water use—prevail across all three production pathways and across multiple end-product types. The graphical summary below presents headline findings by pathway and comparator (Figure 1).



Food applications of egg protein made possible through precision fermentation. Photo credit: Onego Bio

Findings at a glance

BIOMASS FERMENTATION • Edible microbial proteins

Protein rich biomass from fungi, yeast, and bacteria — no livestock required

Comparator	GHG emissions	Land use	Water / scarcity
vs Beef	−80 to −98%	−67 to −98%	−78 to −97%
vs Pork	−48% to −86% / +14% †	−58 to −94%	−60 to −70%
vs Chicken	−16% to −75%	−50 to −94%	varies ‡

Biomass: †GHG vs pork: +14% statistically inconclusive vs German pork under current energy grid (Treml et al. 2026). Land savings are robust across both.
‡ Water use vs chicken: +6% (Quorn mince), -23% (Quorn pieces), -55% (Quorn nuggets); Water scarcity vs chicken: -99% (Bacterial SCP)
Sources: Carbon Trust 2021 · Shahid et al. 2024 · Treml et al. 2026 · Järviö et al., 2021

PRECISION FERMENTATION • Functional proteins

Functional whey & egg proteins produced by fungi and yeast — identical to animal-derived ingredients

Comparator	GHG emissions	Land use	Water / scarcity
vs Dairy protein	−16% to −97% §	−99%	−68 to −96%
vs Egg-white protein	−31% to −74%	−87% to −94%	varies: −86% to +53% §§

Precision Fermentation: §GHG emission benefit low when compared to more efficient New Zealand dairy (Behm et al. 2022). §§ Water direction reversal in Poland driven by egg comparator feed sourcing assumptions, not PF process. Land advantages consistent across all scenarios and geographies.
Sources: Behm et al. 2022 · Briggs et al. 2021 · Hamelin & Cellier 2024 · Järviö et al. 2021 · Leino et al. 2025

MICROBIAL OMEGA-3 OILS • Nutritional oils

DHA- and EPA-rich fish oil alternatives from microbes — no ocean extraction required.
Fisheries benefit likely underestimated in standard LCA

Comparator	GHG emissions	Land use	Eutrophication	Biotic resource use
vs Wild-caught fish oil	−5 to −271%	varies: -16% up to 32x¶	+255% (fresh) to -66% (marine)	−88%
vs Farmed fish oil	−99%	−99%	−99% (fresh)	NR

Microbial oils: ¶ Land use trade-off: microalgal oils consistently require more land than fish oil when crop-based sugars are used as feedstocks — an inherent cost of terrestrial production. This is reduced with waste or gas-derived carbon sources (Bartek et al. 2021). Importantly, this comparison is structurally asymmetric: land use costs of microalgal production are fully visible in LCA, while the fisheries overexploitation and ecosystem depletion associated with fish oil are not captured in standard LCA frameworks.
Sources: Wild caught: Bartek et al. 2021 · Davis et al. 2021 · Dutra et al. 2024 · McKuin et al. 2021; Farmed fish: Togarcheti et al. 2021

Figure 1. Environmental benefits of fermentation-derived ingredients.

Biomass fermentation

Microbial proteins—single-cell proteins made from fungi, bacteria, or yeast—have a number of environmental advantages over conventional protein alternatives:

- GHG emissions: up to 99% lower than beef; up to 86% lower than pork; up to 75% lower than chicken, depending on energy source and production process.
- Land use: Up to 94% less than pork; up to 98% less than beef. Gas fermentation (which uses gaseous inputs such as carbon dioxide or methane as a feedstock) reduces agricultural land requirements by approximately 98% compared to beef — nearly decoupling protein production from land constraints entirely.
- Water use: Up to 70% lower than pork and up to 97% lower than beef.

Global scenario modeling (Humpenöder et al., 2022) finds that substituting just 20% of per-capita ruminant meat consumption with microbial protein by 2050 could roughly halve annual deforestation rates and the CO_2 emissions associated with land-use change.

Precision fermentation

Precision fermentation, which produces functionally equivalent dairy, egg, and other animal proteins, can meaningfully reduce the environmental impact of protein ingredients compared to conventional alternatives:

- GHG emissions: Up to 62-97% lower than conventional U.S. dairy protein, regardless of allocation modeling method; 31–74% lower than egg white protein, with results varying due to electricity grid carbon intensity and feedstock sourcing.
- Land use: 99% lower than conventional dairy; 87–94% lower than egg white production.
- Water use: Up to 97% lower blue water consumption and up to 96% lower water-scarcity impacts, depending on production context and geography; results vary substantially by location.

These reductions are achievable under current commercial conditions, with the largest gains where renewable energy and resource-efficient feedstocks, such as upcycled agricultural crop sidestreams, are available.

Microbial oils

Microbial omega-3 oils—DHA and EPA produced by microalgae and yeast on land—offer a nutritious, resource-efficient alternative to fish oil, addressing both the growing global shortage of marine omega-3s and the environmental costs of ocean extraction:

- GHG emissions: 29–73% lower than wild-caught fish oil when produced using crop-based feedstocks; up to 271% lower when using food-waste-derived feedstocks.
- Pollution: Consistent reductions in marine and freshwater eutrophication, terrestrial acidification, and ecotoxicity — impact categories where conventional (wild-caught or farmed) fish oil performs poorly due to vessel emissions and aquaculture nutrient runoff.
- Marine fisheries depletion: Avoiding marine fisheries depletion is perhaps the strongest environmental argument for microalgal oils; however, it is not often measured using conventional LCA methods.

Fermentation-derived ingredients can deliver environmental and economic value

The evidence reviewed demonstrates that fermentation-derived ingredients deliver measurable environmental benefits across climate, land, water, and ocean impacts—with three factors consistently shaping outcomes across all pathways: energy source, feedstock choice, and production geography. Production processes that leverage renewable energy and next-generation feedstocks, such as agricultural sidestreams, food-waste-derived carbon, and CO_2-based resources, consistently show lower environmental impact.

An analysis of technoeconomic assessments of fermentation-derived ingredients conducted by the Good Food Institute found that microbial proteins are already cost-competitive with comparable conventional protein sources. More data is needed to assess the current cost competitiveness of precision fermentation.

The most significant drivers of cost for fermentation-derived proteins are feedstock costs, capital expenditures, and raw material processing. Feedstock supply and processing also significantly influence the environmental impact of fermentation-derived proteins. Investments in sustainable, resource-efficient next-generation feedstocks and production infrastructure can simultaneously lower both costs and environmental impact.

The barriers to scale are often not scientific, but economic, regulatory, and infrastructure-related. Targeted policy action can close that gap.

Policy recommendations

Accelerate fermentation-derived ingredient production to meet sustainability goals

Incentivize commercial-scale production by providing loans, loan guarantees, manufacturing grants, transferable tax credits, and procurement commitments. Commercial-scale fermentation-derived ingredient facilities generally cost between $100 and $200 million. By providing targeted investments that incentivize commercial infrastructure build-out, governments can help de-risk and attract the necessary private capital to fund scale-up.

Fund open-access research & development. Private sector investment alone cannot meet this challenge within the timeframe required to avert severe depletion of natural resources and climate change. Publicly funded open-access research and development (R&D) is necessary. Strong public investments are crucial to drive innovation in fermentation ingredients, increase competitiveness with animal-based products, and scale the industry's capabilities.

Deploy incentives to support regional bioeconomy hubs

Pilot and demonstration facilities are key for generating the solutions and workforce that the industry requires. Shared pilot plants and scale-up facilities to reduce the CapEx burden on individual companies and accelerate commercialization. Public-private fermentation hubs and contract development and manufacturing organizations (CDMOs) support not only food ingredients but a full range of biobased products, driving regional economic growth alongside sustainability goals.

Regional bioeconomy hubs with shared infrastructure. Co-locating fermentation facilities with industrial decarbonization projects (clean hydrogen, biogenic CO_2 streams, low-carbon heat) can create circular resource systems that simultaneously reduce costs and environmental impacts. Grants, voucher programs, and tax incentives to support manufacturing planning activities and offset costs. Such programs may support engineering plans, site selection, techno-economic assessments, life cycle assessments, and equipment purchase and installation.

Support for low-cost, renewable electricity in biomanufacturing. Energy decarbonization is the highest-leverage environmental improvement available across all fermentation pathways. Policy frameworks that prioritize access to low-cost renewable electricity for bioprocessing facilities would accelerate improvements in environmental performance and drive down operational costs. Examples include industrial rate incentives, on-site renewable energy programs, shared infrastructure investments, power purchase facilitation, and policies promoting energy efficiency and grid access.

Bolster regional feedstock supply chains

Support regionally produced crops for fermentation food-ingredient production. Corn, sugarcane, and sugarbeet are optimal sugar feedstocks for fermentation-derived ingredient production. Tax incentives and grants to support the farming and upcycling of feedstock crops used for fermentation can increase feedstock availability and allow farmers to capitalize on fermentation-derived protein production.

Support development of clean sugar processing facilities. As the fermentation bioeconomy scales, access and supply of cost-effective, sustainable starch and sugar supplies will be critical. Policymakers can ensure that regional crop-processing infrastructure meets the needs of present and future bioproduction demand.

Support development of sustainable feedstock supply chains. Alternative carbon feedstocks from agricultural sidestreams, food waste, and sequestered carbon dioxide can substantially reduce upstream agricultural impacts compared to current sugar crops. Connecting fermentation facilities to local agricultural or food processing sidestreams can create new revenue streams for farmers while supporting circular resource use.

Maintain efficient ingredient regulatory pathways

Efficient, proportionate regulatory pathways. Novel fermentation-derived ingredients should be governed by risk-based regulation and placed on a fair regulatory playing field with conventional ingredients.

Fermentation-derived proteins carry enormous promise to improve food system sustainability, security, and efficiency

GFI’s analysis of more than 30 life cycle assessments of fermentation-derived ingredient production finds clear and consistent benefits across greenhouse gas emissions, water use, and land use when compared to conventional protein production. Additional environmental benefits include lower pollution and water eutrophication and preservation of marine ecosystems. In addition, the fermentation-derived food sector promises more secure, diversified, and efficient supply chains that are less vulnerable to sudden shocks, lower risk of zoonotic disease, product-specific health benefits, new manufacturing jobs, and additional income streams for farmers. Smart, targeted public investments in fermentation-derived protein and oil production can meet sustainability benchmarks while carrying important benefits for food system resilience, national security, and economic development.

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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.

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