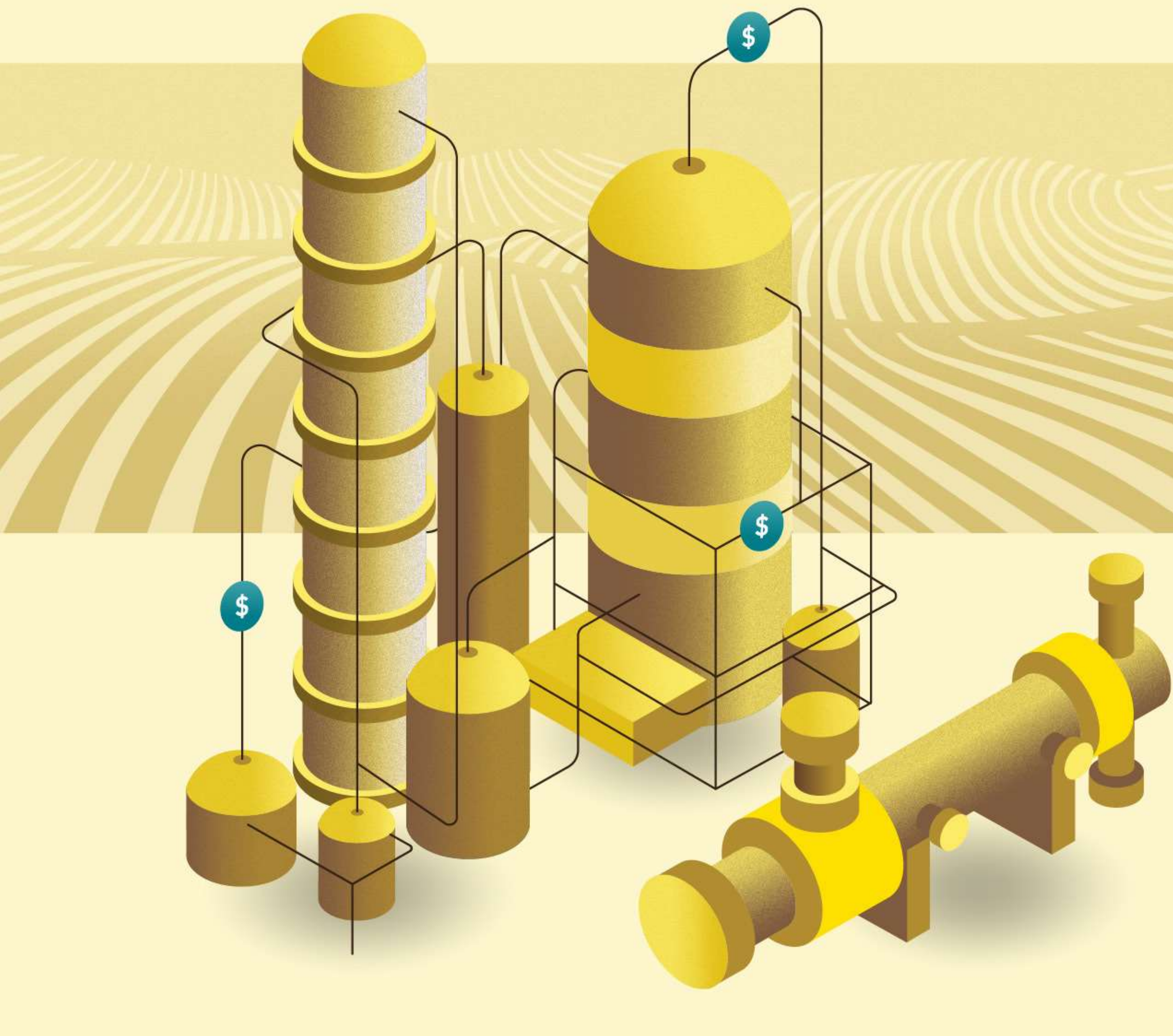
Good Food Institute

Hawkwood

Driving down costs

Insights and recommendations from a meta-analysis of techno-economic models of fermentation-derived ingredients



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About the Good Food Institute

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.

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Executive summary

Fermentation-derived (FD) ingredients are gaining momentum in the alternative protein industry for their potential to match conventional ingredients in cost and taste. As interest grows among stakeholders working to feed the world in increasingly sustainable ways, companies, researchers, investors, and policymakers must understand the economic viability of FD products to drive large-scale investment and rapid technological development of the industry. This report provides the most comprehensive analysis to date of the cost competitiveness and cost drivers of FD ingredients based on a robust review of published techno-economic models (TEMs). By synthesizing existing knowledge, this report equips stakeholders to prioritize research and development needs, assess product targets, and invest in technological and process innovations that can improve the economic viability of FD ingredients—including achieving cost parity with conventional ingredients.

Scope

Techno-economic modeling is essential for evaluating the economic potential of new technologies and pinpointing innovations that enhance cost competitiveness. This analysis reviews published TEMs for three key classes of FD food products: biomass protein, precision fermentation-derived protein, and microbial lipids. The goal was to assess cost competitiveness and identify knowledge gaps and strategies for lowering production costs.

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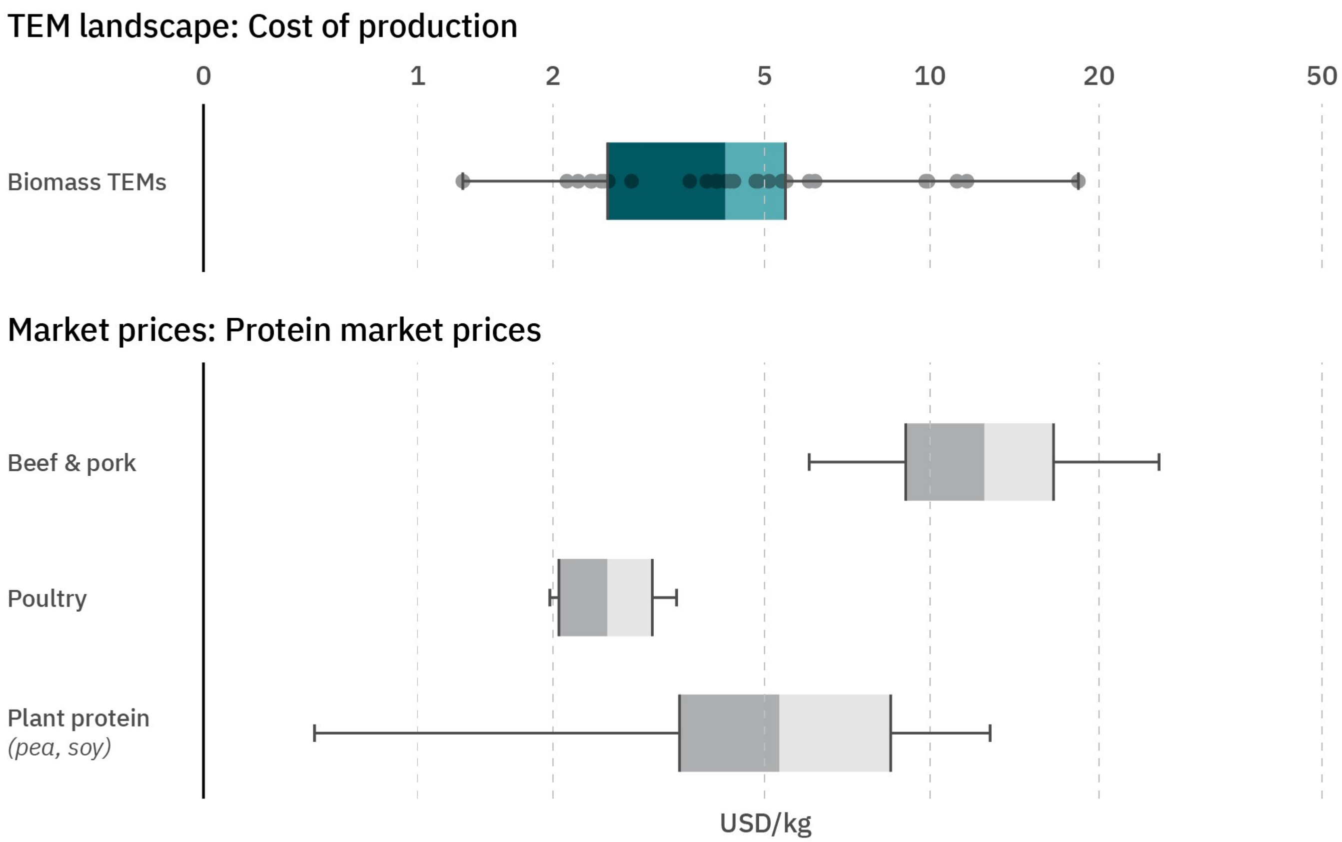

Figure 1. Biomass fermentation ingredient production cost (USD/kg); prices (in USD/kg) approach incumbent commodity ingredient market prices

Key insights

The following insights reflect the study's key findings on FD ingredient cost competitiveness, as well as the critical strategies and knowledge gaps that influence production costs.

1 Biomass proteins are closing the price gap with several incumbent proteins.

- Biomass cost of production (COP) from published TEMs converges around $4–$6 per kg (range $1.3–$18.1 per kg) across all biomass processes (Figure 1). A private case study, grounded in real-world process parameters, predicts a lower COP of $2.5/kg.
- Published and private TEMs suggest that cost parity with incumbent proteins, especially beef and pork, is within reach today. Poultry presents a tighter benchmark, requiring further cost reductions. Competing with commodity plant proteins is more challenging on a per-protein basis, as average biomass COP is at or above soy and pea prices.
- Biomass TEMs were the most prominent among published sources, with 25 models identified, offering broader coverage across fermentation approaches than TEMs for other product types. However, these models typically assume smaller production volumes and lower titers than commercial processes, resulting in higher estimated COP compared to private models.

2 **Limited precision fermentation (PF) TEMs obscure the understanding of progress toward price parity with commodity ingredients.**

- Published COPs were highly variable, ranging from <$20/kg to $14,000/kg, with a notable data gap in the $20–$200/kg range (Figure 2).

- The four published PF TEMs identified offer limited coverage of products and fermentation processes, as cost estimates and process metrics vary widely. Compared to industry benchmarks, these published TEMs underestimate production volume and titer.

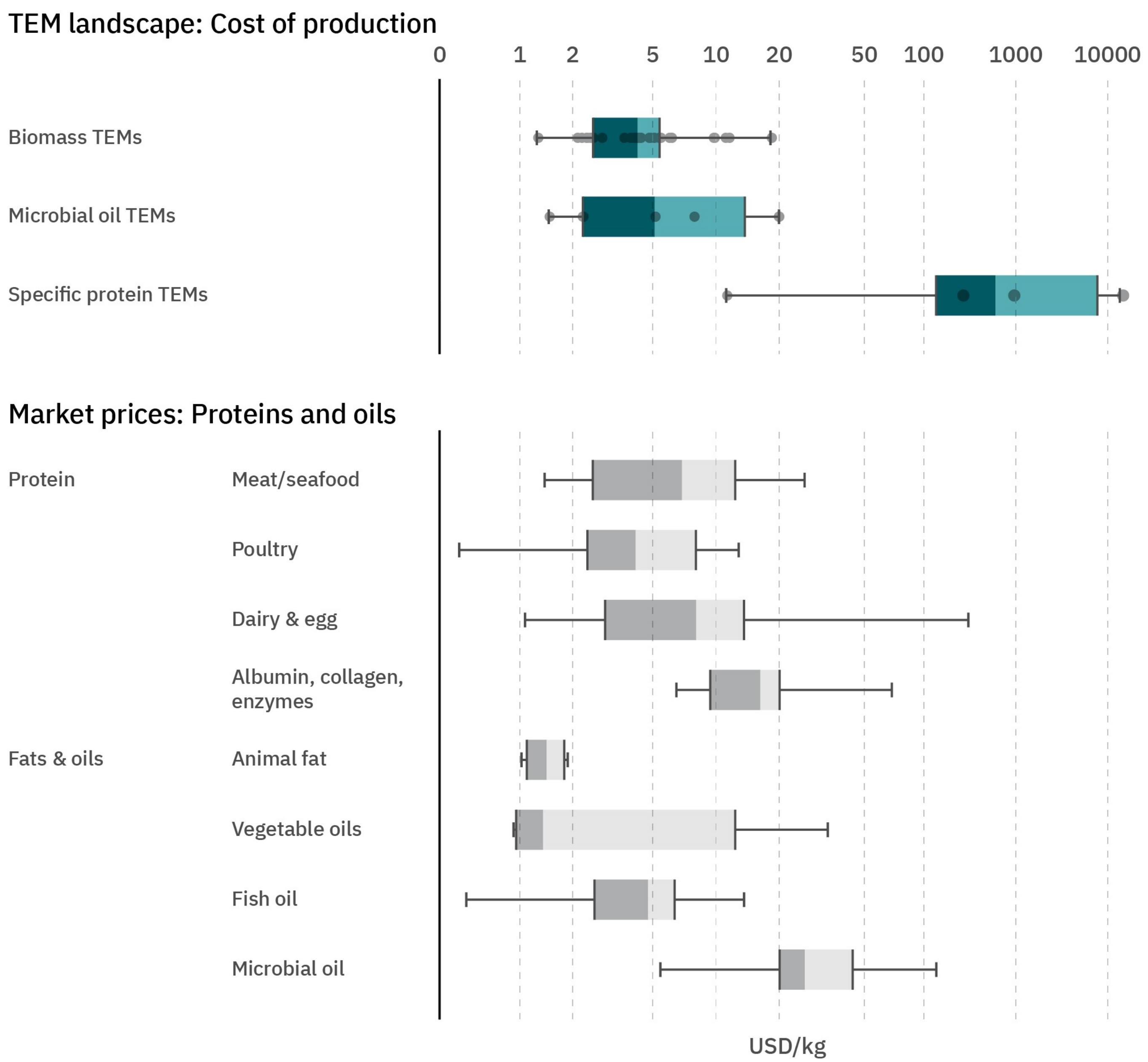

Figure 2. Biomass protein and microbial oil production costs highlight cost competitiveness with select incumbent ingredient market prices (USD)

3 Microbial oils are competitive with some high-value incumbents, but cannot compete on price with commodity oils.

- Microbial oil COP from seven published TEMs ranges from $1.5 to $19.6/kg, with omega-3 oils modeled at the upper end (Figure 2). These costs are far above commodity oil and fat prices. However, certain high-value oils, particularly omega-3-rich oils, are traded at prices that do support these COPs. This finding is reinforced by the successful commercialization of FD omega-3 products today.
- Feedstock cost reduction is needed for microbial oils to compete with commodities.
- The seven public TEMs identified for microbial oils do not reflect the diversity of strains and bioprocesses used in industry. Published TEMs evaluating sucrose or glucose feedstocks generally reflect commercial parameters for production volume and fermentation titer values. Published omega-3 oil TEMs are modeled below commercially relevant scales, indicating further cost reduction potential.

4 Improved feedstock costs, feedstock conversion, and capital efficiency emerge from published TEMs as key levers of cost reduction.

- Public TEMs identify feedstocks and raw material costs, facility capital costs, and performance process metrics as leading COP drivers (Figure 3).

Key cost reduction opportunities:

- Reduce capital costs and improve capital efficiency of Gen 2 sugar and gas feedstock processes to enable optimized economies of scale.
- Improve gaseous Gen 2 feedstock processing efficiency to tap into low-cost feedstocks.
- Increase yield and titer, reduce batch time, and streamline product recovery.

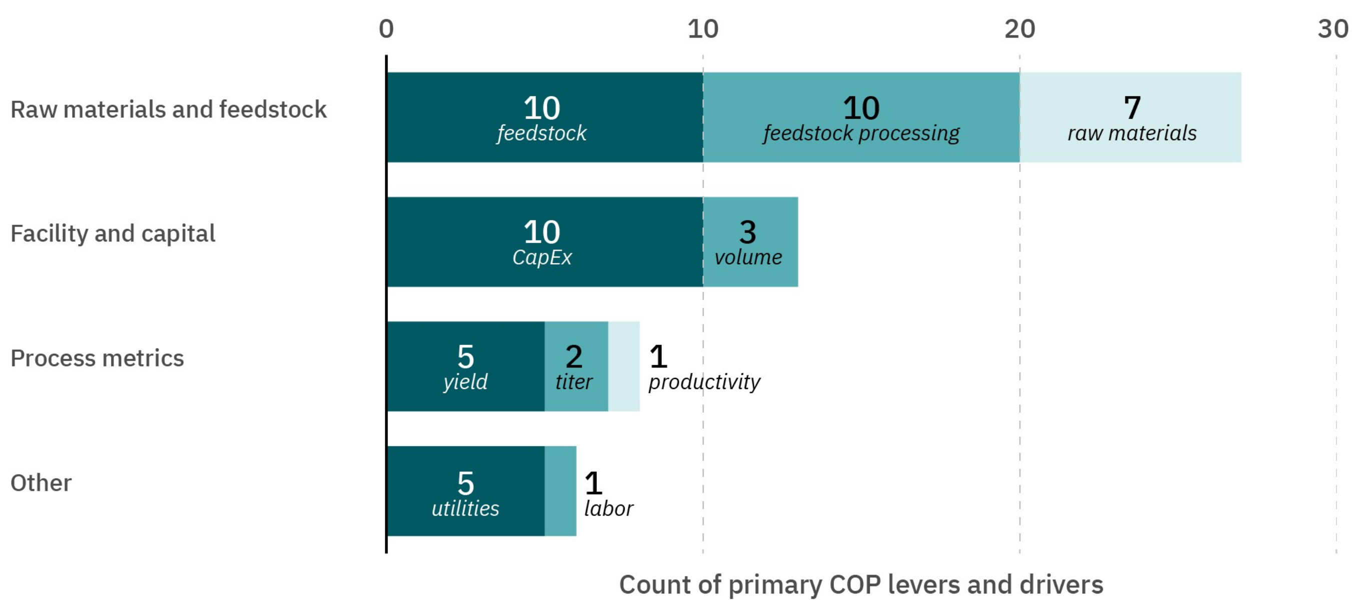

Figure 3. Cost of production driver overview in published TEMs by cost category

Key recommendations

Fermentation-derived food proteins and oils can lead to benefits such as more efficient use of raw materials and reduction in food waste, supply chain stability, new economic opportunities, and national security. These benefits derive primarily from the flexibility and efficiency of fermentation and its use of low-cost agricultural inputs, including sidestreams that may create additional income streams for farmers. The flexibility of fermentation processes and equipment also allows for the production of other goods, like fibers and materials, in fermentation facilities. Despite this promise, current feedstock and raw material costs, facility and capital costs, and unoptimized process metrics create unfavorable economics for FD food protein and oils. Producers, policymakers, and modeling practitioners can play a vital role in driving innovation and enabling cost-competitive, commercial-scale fermentation, as outlined below.

For fermentation ingredient producers

Fermentation-derived ingredient producers can drive the development and cost-competitive commercialization of fermentation through these three actions:

1. Focus commercialization efforts on biomass protein products with favorable COP, as revealed in this analysis.

The economics suggest opportunities to expand production, broaden ingredient applications, and improve cost efficiencies. Due to strong economic potential, producers can allocate resources to overcome remaining commercialization challenges with confidence.

2. Drive innovations that improve costs, including:

- Scale manufacturing through innovations that unlock economies of scale and improve capital expenditure (CapEx) and feedstock efficiency.
- Reduce capital costs and improve process efficiency via novel bioreactor design, and streamlined piping, filtration, and utility optimization.
- Optimize strain development and extraction processes to improve efficiency in utilizing Gen 2 feedstocks (such as agricultural sidestreams, forestry residues, or gases), enabling broader usage and higher feedstock conversion.
- Increase fermentation titer and productivity to reduce unit costs.
- Maximize downstream process recovery—an often underemphasized area in published studies with significant cost impact.

3. Share aggregated industrially relevant cost and process parameters with the research community to support translational research and improve stakeholder recognition of the sector's commercial viability.

Publishing aggregated and anonymized ranges for key performance indicators—such as yield, titer, downstream processing recovery, and vessel volumes—would enable more accurate modeling.

For policymakers

Governments and regulatory agencies can catalyze cost-competitive commercial-scale fermentation using three key policy levers:

1. Fund research and development, including:

- Open-access research into the development and optimization of food-safe high-performing microbial stains, feedstock processing, downstream processing recovery, and specialized equipment such as advanced bioreactors.
- Publicly accessible TEMs for fermentation-derived ingredients with high-volume opportunities like whey, casein, egg white proteins, and omega-3 oils.

2. Leverage incentives to support scale up and manufacturing, such as:

- Investments that support the creation of public-private fermentation hubs with shared pilot plants and scale-up facilities to reduce the CapEx burden on individual companies. These contract manufacturing and development organizations can enable efficient commercial scale up and support regional economies.
- Support for low-cost electricity in biomanufacturing, such as industrial rate incentives, on-site renewable energy programs, shared infrastructure investments, power purchase facilitation, and policies promoting energy efficiency and grid access.
- 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.
- Incorporation of foods with fermentation-derived protein and oil ingredients into public procurement, including for the military and humanitarian assistance food channels.
- Loan programs that offer lower interest rates to reduce the impact of CapEx on the cost of production.

3. Support the standardization of techno-economic data analysis, for example:

Best practices, data and parameter standardization, reporting metrics, and model assumptions of TEMs to enhance accuracy, comparability, and practical relevance.

For techno-economic modeling practitioners

Practitioners across sectors can enhance the impact of TEM for the industry by focusing on two priority activities:

1. Standardize best practices for FD biomanufacturing TEMs.

Best practices should establish input and output standards, flexible frameworks, and accurate modeling of upstream and downstream processing, while properly accounting for scaling effects and key bioprocessing parameters. Models should be published with detailed input and reporting parameters to enhance transparency. Just as ISO standards guide life cycle assessment and carbon accounting, a similar framework for TEMs would improve the quality and reliability of available models.

2. Publish TEMs across a wide range of fermentation-derived protein and oil pathways to benchmark current performance and highlight opportunities.

This analysis uncovered a lack of publicly available TEMs to evaluate many current commercial processes operating at full scale. These include precision FD beta-lactoglobulin, edible microbial oils, and a wide range of mycoproteins. Modelers must strike a balance between protecting proprietary data and maintaining competitive advantage, while still sharing process metrics that are useful and informative to the broader field. Developing approaches that enable meaningful benchmarking without disclosing sensitive details is critical to advancing collective understanding.