European Commission

Study on biomass and precision fermentation

Executive Summary

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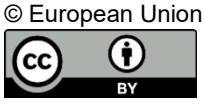

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1. State of play of biomass and precision fermentation in the EU

This study examines how the development and scaling-up of biomass and precision fermentation for the production of proteins for food and feed may affect the EU farming sector and rural areas in the medium and long term. Particular attention is given to the implications for conventional agricultural markets and production systems, the competitiveness and economic sustainability of EU farmers, the EU's dependence on imported proteins, and the policy conditions under which potential benefits for agriculture may be realised. Biomass and precision fermentation are emerging as part of a wider shift in the protein economy, but their development remains uneven. The technologies are attracting growing scientific, industrial and policy attention because they may contribute to protein diversification, reduce pressure on land and water resources, and create new food and feed ingredients. However, their current role in protein production in the EU remains limited by a combination of factors: uneven technological readiness, high production costs, scale-up constraints and regulatory uncertainty for some applications. The focus of biomass and precision fermentation technologies is not generally the direct production of finished food or feed products. Rather, they produce microbial biomass or specific protein ingredients that may then be used by food and feed manufacturers in a wider formulation. In this respect, microbial proteins should be understood primarily as ingredients or functional inputs within food and feed value chains, not as stand-alone replacements for meat, milk or eggs. Biomass fermentation and precision fermentation both rely on microorganisms, but they differ in what the production process is designed to deliver. In biomass fermentation, microorganisms are cultivated so that the microbial cells themselves become the main protein product. The resulting biomass may be used whole, or after limited processing, as a protein-rich ingredient for food or feed. Mycoprotein is the most established example, and other pathways include yeast, bacterial and fungal biomass grown on sugar-based substrates, side-streams, methane, carbon dioxide or other inputs. Precision fermentation uses microorganisms as production platforms, or cell factories, to produce specific target molecules. These are usually individual proteins or other high-value functional ingredients, such as dairy proteins, egg white proteins, haem proteins or speciality nutrition ingredients.

This distinction is important for assessing market impacts. Biomass fermentation is more relevant where microbial biomass can serve as a bulk or semi-bulk protein ingredient, particularly in feed or in some whole-biomass food applications. Precision fermentation is less suited to bulk dietary protein production under current conditions, because the production of specific heterologous proteins creates yield constraints and requires more extensive downstream processing. Its more credible near- and medium-term role is therefore functional substitution: producing selected proteins that replicate the

techno-functional properties of specific animal-derived ingredients, rather than replacing conventional agricultural products by volume. At present, biomass fermentation appears closer to commercial scaling than most precision fermentation applications. Feed applications, and particularly aquaculture, pet food and specialised feed inputs, currently offer a more accessible route to market than many human food applications. Food uses remain more constrained by cost, consumer acceptance, and the need for pre-market authorisation under the EU novel food framework.

The sector's development is shaped by four main factors. First, energy demand. Fermentation facilities require aeration, agitation, cooling, sterilisation and drying or downstream processing, all of which can be energy-intensive. The environmental and economic performance of microbial proteins therefore depends strongly on the cost and carbon intensity of the energy used. Secondly, feedstock choice. Refined sugars offer predictable performance but expose producers to input costs and competition with other uses. Side-streams, residues, gaseous substrates or lower-cost biomass may improve the economic and environmental profile, but they introduce challenges linked to quality, logistics, pre-processing and regulatory treatment. Thirdly, downstream processing. It is relatively lighter for biomass fermentation, where the microbial cell is often the product, but substantially heavier for precision fermentation, where the target protein must usually be separated and purified. Fourthly, regulatory clarity and market authorisation. They influence both investment decisions and market entry, especially for food applications. The cost structure remains the main barrier to large-scale competitiveness. Fermentation-based systems operate as industrial bioprocesses. They require high capital expenditure for bioreactors, control systems, sterilisation infrastructure and product recovery. Precision fermentation normally requires additional purification infrastructure, such as filtration, chromatography and concentration units, which raises both capital and operating costs. Biomass fermentation is also capital-intensive, but whole-biomass applications can avoid some of the more expensive purification steps needed in precision fermentation. Variable costs are equally important. Feedstock costs represent a major share of production costs, particularly where refined sugars are used. Energy costs are also significant, especially because microbial growth generates heat that must be removed from large-scale bioreactors. Skilled labour, maintenance, process monitoring, quality assurance and regulatory compliance further add to operating costs. In comparison, conventional animal and plant protein sectors benefit from mature infrastructure, established supply chains, economies of scale, even though they also face important input costs, notably feed, fertilisers, energy, labour and land. Overall, the current state of play points to a sector with considerable technical potential, but also with substantial scale-up risks. Albeit with important exceptions, many firms remain at pilot, demonstration or early commercial stage. Cost parity with conventional proteins is not simply a matter of increasing production volumes: scaling can amplify losses if process efficiency, energy use, feedstock cost and downstream processing are not sufficiently optimised.

2. Scenarios and implications for agricultural markets in the medium and long term

Given the uncertainty surrounding the future development of biomass and precision fermentation, and the limited availability of quantitative data, the study uses a foresight approach rather than presenting a single forecast. Four scenarios were developed to explore how different combinations of competitiveness, market acceptance, regulatory conditions and policy support could shape the relationship between microbial proteins, agricultural markets and rural value chains by 2030 and 2050. Among these, Scenario 3 represents the most favourable pathway, as it combines strong EU value-chain competitiveness and acceptance with an enabling policy and regulatory environment. Under this scenario, microbial proteins are more likely to scale within the EU, become connected to agricultural value chains, and create opportunities for farmers through feedstock supply, side-stream valorisation, local processing and the use of fermentation-based inputs. The other scenarios differ in their assumptions, but broadly point to more limited or externally driven development, with fewer benefits captured by EU farmers. Across all scenarios, the medium-term impact of the introduction of microbial proteins on conventional agriculture is expected to remain limited. By 2030, microbial proteins are unlikely to cause broad displacement of conventional animal or plant proteins. Their effects are more likely to appear in premium applications and feed-related niches. In the longer term, the implications could become more significant, but only under specific conditions. By 2050, stronger effects may emerge if production costs decrease substantially, regulatory pathways become more predictable, consumer and industry acceptance increases, and EU-based firms are able to scale production. In that case, microbial proteins could gain a more visible role in food manufacturing, functional ingredients and feed applications. The effects would still be selective rather than uniform.

When it comes to the impact on conventional farming systems, the dairy sector is among the most exposed, but the implications are mixed. Precision fermentation may compete in specialised dairy proteins, functional ingredients and individual milk components, especially in higher-value food and nutrition markets If these products scale significantly, they could reduce demand for specific milk components. At the same time, dairy processors and cooperatives may be relatively well placed to adapt because they already have capabilities in protein processing, ingredient innovation and biotechnology. Dairy is therefore both exposed to substitution pressure and potentially able to capture value if EU-based fermentation value chains develop. Microbial proteins are not expected to replace beef as a whole product in the same way they may compete with selected dairy or egg ingredients. Beef exposure is therefore mainly indirect, linked to broader developments in hybrid or alternative protein markets – such as plant-based proteins. Egg ingredients are also clearly exposed. Egg proteins are used in food manufacturing for e.g. foaming, emulsification and binding. These

functions are easier to replicate than the sensory and structural characteristics of whole animal products. The likely impact is therefore concentrated in bakery, processed foods and industrial ingredient markets. Table eggs are completely unaffected, as fermentation cannot replace the whole product in the same way.

Pigmeat and poultry are less exposed to direct product substitution than dairy or egg ingredients, but they are strategically relevant because of their dependence on feed markets. These sectors are highly sensitive to feed prices, imported protein sources and access to functional inputs such as amino acids, vitamins, enzymes and specialised feed ingredients. This creates both a risk and an opportunity. If microbial protein value chains and related fermentation-based inputs are developed competitively outside the EU, EU pig and poultry producers could face indirect pressure from competitors with cheaper or more efficient feed systems. Conversely, if these inputs are produced accessibly and at scale within the EU, they could improve feed formulation, reduce dependence on selected imported inputs and support more efficient production. For pigmeat and poultry, the key issue is therefore whether the EU can develop accessible fermentation-based feed inputs at scale, strengthening the feed base on which these sectors depend. Crop sectors are the most likely to benefit directly. Sugar, starch, cereals, potatoes and other carbohydrate-rich crops may supply feedstocks for fermentation. Agricultural side-streams and residues may also create opportunities, provided that quality, logistics, pre-treatment and regulatory issues can be managed. These opportunities are strongest where fermentation plants are located close to agricultural production and where farmers can participate through stable contracts, cooperatives or regional value chains. Under restrictive scenarios, the main risk is missed opportunity rather than direct loss.

Long-term outcomes will depend less on substitution alone than on value-chain organisation: whether production is anchored in EU feedstocks, processing capacity and rural infrastructure, or develops mainly outside the EU. If production is anchored in Europe, microbial proteins could support new outlets for crops and side-streams, improve access to feed-related inputs, and create new forms of value capture in rural areas. The contribution of microbial proteins to reducing EU dependence on imported proteins is expected to be limited and supplementary. Even under favourable development pathways, they are unlikely to deliver a major reduction in overall import dependence within the time horizon considered. Their main relevance lies in diversification and resilience rather than in the substantial replacement of existing imported protein sources. In this context, resilience refers to the ability of the EU protein system to rely on a broader portfolio of protein and feed-input sources, including some produced from EU-based feedstocks, side-streams or processing capacity. Microbial proteins may broaden the range of protein and feed-input options available to the EU, particularly in specialised food ingredients and feed-related inputs, improving flexibility in feed and ingredient formulation. Their strategic value therefore depends on whether production is located in Europe and linked to EU feedstocks, processing capacity and value chains. Otherwise, reliance on imported microbial

proteins, feedstocks, inputs or externally controlled technologies may simply change the form of dependency rather than reduce it.

3. Opportunities and challenges for farmers and rural economies

The opportunities offered by biomass and precision fermentation are significant, but they are conditional. They depend less on the existence of the technologies themselves than on how value chains are organised, where processing takes place, who owns the assets and whether farmers are connected to higher-value activities. The most direct opportunity for farmers lies in feedstock supply. This could diversify farm income, support longer-term contracts and strengthen links between agriculture and bio-based industry. For some regions, particularly those with existing sugar, starch, brewing, dairy or biorefinery infrastructure, fermentation may support new rural industrial clusters. A second opportunity concerns the use of fermentation-derived products on farms. Livestock producers, especially in pig, poultry and aquaculture systems, may benefit from more tailored feed ingredients, amino acids, enzymes, vitamins and microbial proteins. These inputs could improve feed efficiency, reduce nutrient losses and strengthen the resilience of feed supply chains. Fermentation may also contribute to the broader rural bioeconomy through links with biofertilisers, biopesticides, side-stream valorisation, biogas, biomass hubs and local processing. A third opportunity concerns farmer participation beyond commodity supply. Cooperatives, producer organisations and regional partnerships could help farmers capture more value by investing in processing, negotiating contracts, aggregating feedstocks or participating in ownership models. This is particularly important because the highest value in fermentation value chains is likely to lie downstream, in processing, technology, intellectual property, formulation and market access.

The challenges are equally important. The first is economic viability. Fermentation remains costly, and many potential farm benefits depend on scale-up that has not yet been achieved. Demand for feedstocks may be too small, too volatile or too concentrated to benefit many farmers in the medium term. Side-stream valorisation may appear attractive, but residues are not automatically usable: they may require pre-processing, quality control, separation, storage, transport and regulatory clarification. The second challenge is bargaining power. Farmers may be integrated into fermentation value chains mainly as suppliers of low-margin raw materials, while value is captured by processors, technology providers or downstream food companies. Without cooperative models, contractual safeguards or local ownership opportunities, the sector could reproduce familiar asymmetries in agri-food value chains. The third challenge is territorial unevenness. Fermentation is likely to favour regions with suitable feedstocks, industrial infrastructure, energy access, skilled labour, logistics and existing processing capacity. Large arable regions and areas with sugar or starch industries may be better placed than more remote, livestock-dependent or structurally weaker rural areas. Without targeted support, the technology could widen rather than narrow territorial disparities. Finally, there is a strategic

challenge for the EU. If fermentation scales elsewhere while the EU development of production of microbial proteins remains slow, fragmented or dependent on external inputs, European farmers may face competition from imported innovation without benefiting from domestic value creation. The key question is therefore how fermentation is integrated into European agriculture, and on whose terms.

4. Policy response and support mechanisms

The policy question is not whether biomass and precision fermentation should simply be promoted or restrained, but how their development can be shaped so that farmers and rural areas capture value rather than merely supply inputs or absorb adjustment pressures. The foresight evidence suggests that policy should act as a shaping force: it can influence whether microbial protein value chains develop as European, agriculturally embedded systems, or as markets supplied mainly from elsewhere. Three priorities emerge. First, farmers' bargaining power should be strengthened early, before contracting structures and buyer power become locked in. Producer organisations, cooperatives, written contracts, transparent price formulas and value-sharing clauses can help ensure that farmers enter fermentation-linked feedstock chains on fairer terms. Second, public support should prioritise territorially anchored investment and local value capture. Support for biomass hubs, side-stream aggregation, storage, drying, local pre-processing and farmer-facing pilot chains should be conditional on a meaningful role for farmers or cooperatives, so that rural areas retain more than a raw-material margin. Third, regulatory and side-stream certainty should be addressed before large-scale deployment. Clearer guidance on food, feed, inputs, by-products, end-of-waste status and authorisation pathways would reduce uncertainty and prevent immature circularity claims from becoming speculative promises. Other support mechanisms should be treated as design conditions for these priorities rather than as a separate list of measures. Advisory services, demonstration projects, innovation platforms, targeted support for exposed sectors, input-side resilience for livestock systems, skills development, regional targeting and risk-sharing finance can all help mitigate risks, but only if they are linked to farmer participation, territorial embedding and credible value-chain development.

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