



Ingredient Innovation: Pathways to Resilient Food Systems Food Innovators Network

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Contents

Introduction	3
Context and rationale	4
Three pathways of ingredient innovation	5
Pathway 1: Diversified crops and feed systems	5
Pathway 2: Biotechnology-enabled ingredients	5
Pathway 3: Circular and waste-derived ingredients	6
Enablers for adoption	7
Conclusion	8
Contributors	9
Endnotes	10

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Introduction

Food systems must expand access to healthy diets while operating within tightening land, water and climate limits. Yield growth in staple crops has slowed, climate variability is driving wider swings in output, and reliance on a narrow set of inputs leaves supply chains more exposed to shocks. With climate risks already evident, food and feed systems alike need diversified portfolios of inputs that can function through more frequent and severe disruptions.

A key risk is reliance on a narrow set of crops and inputs. Maize, wheat, rice and soy dominate calories and feed. Due to this concentration, price volatility thins producer margins and bloats consumer prices.¹ For farmers, this dependence narrows income opportunities and exposes them to volatile markets. Demand for proteins, edible oils and functional ingredients is expected to rise globally towards 2050, reflecting projected population growth and dietary shifts, even as consumption already exceeds needs in some regions – which will increase exposure to supply shocks and market volatility if input sources are not diversified.²

An ingredient-level lens provides a practical entry point. Here, “ingredient” refers to the materials used in food and feed formulations obtained through crops, biotechnology or circular routes. Diversifying inputs adds options that maintain functionality during shocks, reduce dependence on climate-sensitive commodities, and create more stable income for farmers.

This paper frames ingredient innovation as an upstream strategy for resilience and adaptation across three pathways with near-term potential: diversified crops and feed systems, biotechnology-enabled ingredients, and circular and waste-derived routes.

It is developed by the World Economic Forum’s Food Innovators Network, a global platform that convenes thematic “sprints” to accelerate food innovation. The sprint on Ingredient Innovation brings together public and private partners to align innovation with procurement, policy and finance.



Context and rationale

The past decade of food innovation demonstrated both the potential and the limits of end-product strategies. Novel feed innovations, plant-based meats and cultivated proteins established proof of concept, but uptake plateaued due to uneven consumer acceptance and limited financing.³ These dynamics underscore that technological innovation is necessary but not sufficient for systemic change. Progress also depends on policy, procurement, finance and institutional arrangements that connect new products with nutrition and farmer livelihoods.

Investment in climate-tolerant crops, alternative feedstocks and upcycling side streams has expanded, but adoption remains patchy. Smallholder farmers, who face lower returns, higher risks and limited access to land, credit and inputs, continue to rely on a narrow set of staples. Livestock and aquaculture producers remain exposed to imported maize, soy and fishmeal, and many by-products are underutilized. Without stronger integration with markets, procurement and agri-food systems, these innovations struggle to move beyond pilots.

Taken together, these experiences suggest that an ingredient-level innovation can be leveraged as an upstream enabler across three pathways: diversified crops and feed systems,

biotechnology-enabled ingredients, and circular and waste-derived routes. Each is largely technological in nature, but their success will depend on non-technical enablers such as procurement incentives, risk-sharing mechanisms and fair value distribution. Balancing improved farmer incomes with consumer affordability will be essential for scale.

This perspective shifts the emphasis from competing against entrenched consumer categories to broadening the pool of verified inputs that supply chains can draw on. It aligns innovation with levers for resilience: feed cost structures, supply stability, nutritional adequacy and lower emissions than today's food system.

Positioning innovation at the ingredient level emphasizes complementarity. Cultivated and fermentation-derived components can be integrated into processed foods and feeds; drought-tolerant crops and pulses can be scaled through public procurement and nutrition programmes; and upcycling side streams can create new revenue streams for farmers. Each pathway is distinct, but together they represent a portfolio of options to reduce volatility, diversify nutrition and strengthen resilience in a changing climate.



Three pathways of ingredient innovation



Pathway 1: Diversified crops and feed systems

Food and feed systems remain heavily dependent on a small number of globally traded crops. Maize, wheat, rice and soy dominate calorie supply and underpin much of the feed used in livestock, poultry and aquaculture production. This concentration creates systemic exposure: when climate or market shocks disrupt one of these commodities, costs transmit quickly through value chains. Feed alone represents 50-70% of operating costs in animal production, so volatility in soy or maize prices affects both producer margins and consumer affordability. Producers (especially smallholders and small and medium-sized enterprises (SMEs)) struggle with volatile input prices, inconsistent quality and poor local supply chains.

Challenges such as reduced margins and constrained productivity act as bottlenecks to sector growth, making feed one of the most direct levers to stabilize and expand protein availability. The Southern Africa Poultry Initiative (SAPI) is advancing feed diversification by integrating locally adapted cereals, pulses and alternative proteins such as black soldier fly into poultry value chains, demonstrating how substitution can stabilize costs and diversify markets.

Diversifying crops and feedstocks offers a pathway to broaden sourcing and strengthen resilience. Climate-tolerant cereals such as millets, sorghum and pulses, and salt-tolerant crops like halophytes can be integrated into feed rations, reducing reliance on imports while creating new markets for farmers.⁴ Novel proteins derived from insects, algae or microbial processes can further replace portions of fishmeal and soymeal in poultry and aquaculture diets, helping to stabilize costs and reduce pressure on wild fisheries.⁵

Localized production of diversified feed inputs creates new revenue streams for farmers, reduces exposure to import volatility and supports more inclusive growth across poultry, livestock and aquaculture. For consumers, more stable feed supply translates into greater affordability of animal-derived foods, which remain an important source of accessible protein in many regions. By valorizing underutilized crops and co-products, diversified feed systems contribute to efficiency and improved climate performance.

These strategies highlight the need to balance more stable incomes for producers with lower costs for consumers, ensuring both sides of the value chain benefit.



Pathway 2: Biotechnology-enabled ingredients

Food systems depend on functional proteins and fats that underpin product performance. Casein, whey, albumin, collagen and structured lipids all play critical roles in emulsification, binding, foaming, texture and nutrition. Yet these are largely tied to conventional livestock and dairy chains, leaving them exposed to climate volatility and market disruptions.

Independent analysis has begun to show economic progress in cultivated proteins. In 2025, Aleph Farms commissioned a techno-economic assessment of cultivated beef cuts showing production could be cost-competitive and profitable at price parity with conventional beef.⁶ This points to the potential for cultivated platforms to supply functional proteins and fats as viable inputs alongside conventional agriculture, when the right production processes and product strategy are implemented.

Biotechnology provides an option to diversify this set of inputs with more predictable supply while also reducing resource intensity. Precision fermentation, biomass fermentation and cultivated platforms can generate proteins, lipids and bioactive molecules with defined functionality for use in various food products. At the ingredient level, these can be added in small amounts to stabilize formulations and improve nutrition.

The value of this pathway lies in complementing proteins. By enabling new sources of fermented, cultivated and conventional ingredients, biotechnology can diversify sourcing while preserving the taste, texture and familiarity that consumers consistently prioritize, creating opportunities for balanced protein approaches, where animal-derived and novel proteins work together to reduce environmental impact while maintaining affordability and consumer familiarity.

Production remains capital- and energy-intensive, regulatory frameworks differ by jurisdiction, and consumer familiarity with these products is still limited. Even if technical maturity continues to

improve, broader resilience outcomes will depend on whether adoption aligns with the needs of both consumers and traditional producers. Scaling will require consistent quality, cost trajectories that make sense in procurement, and communication that positions biotechnology not as a replacement but as a tool to diversify and strengthen existing food systems. As with other pathways, technical feasibility alone will not guarantee adoption. Aligning producer interests, managing costs for consumers and ensuring equitable value distribution will determine whether these platforms can scale.



Pathway 3: Circular and waste-derived ingredients

Circular approaches may offer near-term opportunities, optimizing existing materials with fewer behavioural shifts. Large volumes of agricultural residues and food-processing by-products are still discarded, underutilized or used in low-value ways. At the same time, feed systems depend on volatile imports of soymeal and fishmeal, and food manufacturers face limited options to source affordable, high-quality proteins and oils.

This gap reflects both a vulnerability and an opportunity: better use of what is already produced can improve nutrition, stabilize supply and create additional revenue streams for farmers.

Circular approaches address this by turning side streams into proteins, oils and fibres that can be reintegrated into livestock feed. Insects reared on residues, fungi or bacteria that upcycle local waste streams, microbial proteins from gases or waste sugars, and oilseed cakes are examples demonstrating valorization of side-streams.⁷⁷

These routes are primarily targeted at feed markets, where even partial inclusion can improve resilience by reducing dependence on imported feedstocks. In the longer term, some applications may extend to food-grade ingredients where safety and consistency are demonstrated.

At the ingredient level, these pathways support resource efficiency by capturing value from materials already in circulation, strengthen local resilience when production occurs near demand centres, and create income opportunities for farmers. By monetizing residues, circular and waste-derived ingredients can contribute to affordability, resilience and climate goals in ways that complement, and not depend on, breakthroughs elsewhere.

Enablers for adoption

Despite significant technical progress, the adoption of diversified food and feed ingredients continues to lag climate pressures and rising demand. The central challenge is sequencing: companies seek proven supply before committing, while innovators need early demand. The result is that many promising solutions remain on the margins of mainstream supply chains.

Shared application contexts are one such enabler. New proteins, fats and fibres gain traction when they address immediate system challenges, such as stabilizing feed supply, reducing dependence on volatile imports or improving nutrition in institutional settings. When innovators, buyers and producers agree on where an ingredient provides clear near-term value, investment and procurement decisions become easier.

Pre-competitive exchange reduces first-mover risk. Few companies are willing to carry adoption costs alone when returns remain uncertain. Neutral platforms that allow firms to share performance data, methodologies and standards help establish common baselines. This reduces duplication, improves comparability across trials and lowers the costs of determining when an ingredient is ready for integration into supply chains.

Partnerships that connect business, government, producers and finance provide the infrastructure needed for scale. Coordinated investment in processing capacity or regulatory assessments can bridge the gap between technical readiness and commercial maturity.

When these partnerships focus on shared outcomes such as climate adaptation, nutrition and resilience, they ensure that public and private resources support system-wide benefits. The European Agri-Food Biotech Alliance, convened by EIT Food, provides one such mechanism by

connecting industry, researchers, start-ups and policy-makers to overcome fragmentation, and accelerate biotechnology solutions that enhance Europe's strategic resilience while building a more sustainable and competitive food system.

Consumer demand is as important as supply-side enablers for food ingredients. Expectations around health, sustainability and protein availability shape corporate sourcing and influence adoption decisions. For many larger companies, clarity on consumer acceptance is a core part of the risk calculation when considering new ingredients. Clear labelling and consumer education can support informed choices, while subsidies, already common in other parts of the food system, may also influence adoption pathways. For feed applications, cost, consistency and performance remain the main drivers.

Ultimately, however, adoption will depend on creating a significant economic case. Substitution will only occur at scale when novel ingredients can match or undercut the cost of conventional options, which is complicated by entrenched subsidy structures. For farmers, especially a new generation considering entry, viable income and predictable returns are decisive. Sustainability and resilience are important drivers, but cost parity and supply assurance remain decisive for widespread integration.

Taken together, these conditions suggest that ingredient innovation is moving forward, but the pace must accelerate. Clear application contexts, mechanisms for collective evaluation, partnerships that spread risk and an economic case that works for farmers and producers can shorten the distance from pilot to practice. Strengthening smallholder economics broadens production, reducing supply shocks and reliance on few crops. With these in place, ingredient innovation can become a central tool in building food systems that are more resilient, sustainable and capable of meeting future demand.

Conclusion

Meeting the needs of a growing global population while remaining within environmental limits will require a broader portfolio of reliable inputs. By diversifying crops and feed systems, expanding biotechnology-enabled ingredients and valorizing side streams, food and feed supply chains can build resilience and reduce exposure to concentrated commodity value chains.

The contributions of the three pathways are complementary and distinct. Diversified crops and feed systems broaden sourcing and strengthen farmer livelihoods. Biotechnology-enabled ingredients expand the range of functional components available for reformulation and supply stability. Circular pathways capture value from existing outputs, improving efficiency and creating localized protein and oil supplies. Together, they illustrate how innovation can increase production while reducing environmental pressure.

Adoption will depend on supportive policy and regulation, procurement that allows substitution, finance aligned to scale, and collaboration on evidence. Next steps include building a stronger economic case for ingredient diversification, aligning producer and buyer interests, and ensuring farmers benefit as new ingredient markets grow.

The Food Innovators Network can take this forward by convening partners to define shared priorities, advance evidence on costs and benefits, and explore procurement tools such as contracts for difference that accelerate adoption. With these conditions in place, ingredient innovation can become a cornerstone of adaptation, supporting food systems that are both more resilient and more sustainable.



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