

Advancing Nutrition in Alternative Proteins: The Role of Food Technologies

A landscape analysis of how production platforms, ingredients, and processing methods shape nutritional outcomes in alternative protein.



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Nutrition Is a Critical Frontier in Alternative Protein Innovation

03



As the alternative protein industry scales, nutritional impact is becoming as critical as taste, texture, and cost. While protein content has been the early focus, the next generation of products must go further — delivering improved bioavailability, micronutrient density, lipid functionality, and reduced anti-nutrients.

This report offers a data-driven view of where the sector is innovating today — and where deeper scientific collaboration is still needed to realize the full health promise of alternative proteins.

By mapping solutions across companies, patents, and peer-reviewed research, we aim to equip scientists, developers, and partners with the insights needed to accelerate progress.

Where Innovation Is Concentrated—and Where Gaps Remain

04

Advances

Protein Quality Enhancement

- Focus on completeness and digestibility, often via fermentation, germination, and enzymatic treatment to boost bioavailability.

Micronutrient Fortification

- Iron, vitamin B12, and zinc are the most frequently targeted nutrients. Fortification is especially common in extrusion-based and hybrid processes; however, few strategies explicitly address bioavailability.

Lipid Structuring & Healthy Fat Delivery

- Techniques like oleogelation and encapsulated oils are replicating animal fats while improving nutrition, especially in high-moisture extrusion.

Gaps

Antinutrient Mitigation

- Despite known impacts, few technologies actively reduce antinutrients. Most rely on incidental reduction from extrusion or fermentation.

Sodium Strategy Integration

- Small subset of companies apply sodium reduction as a core design target, with most relying on naturally low-sodium ingredients or offering limited data.

Data & Disclosure Gaps

- Many technologies score zero—not for poor performance, but due to limited or unreported nutritional data.

Key Insight

Fermentation and extrusion are the backbone of innovation.

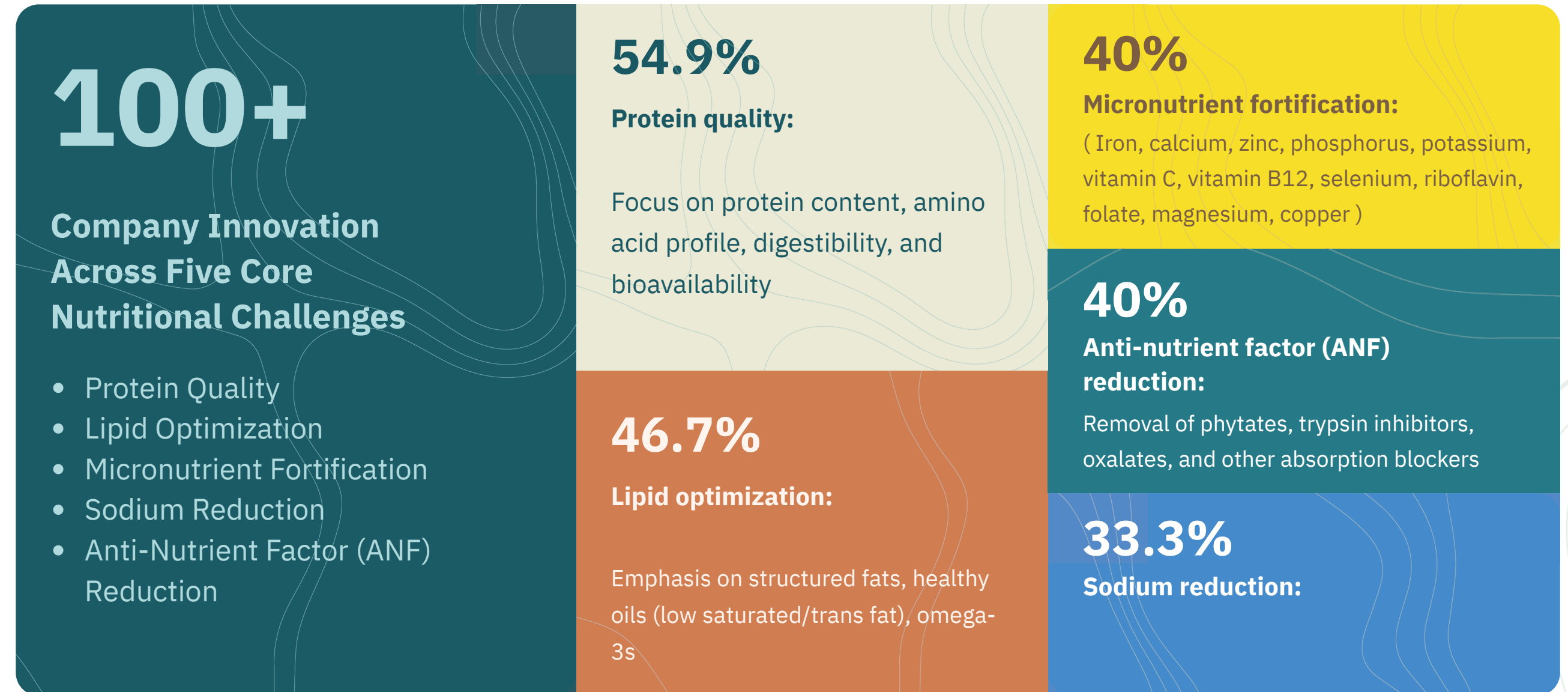
These foundational technologies consistently drive nutritional improvements across multiple fronts — enhancing protein quality, boosting micronutrient bioavailability, and reducing antinutrients — making them critical enablers in alternative protein product development.

Our Approach: Mapping Technologies, Claims, and Nutritional Outcomes

How We Built This

We analyzed:

- 462 companies across plant-based, fermentation, and hybrid platforms
- 19 patents and 37 peer-reviewed publications (2022–2025)



Our analysis focused on five nutrition priorities: protein quality, sodium reduction, lipid optimization, micronutrient fortification, and anti-nutrient reduction.

We triangulated company claims, scientific literature, and expert interviews to produce a cross-cutting view of innovation momentum, maturity, and whitespace across the alternative protein ecosystem.

Evidence Base: Trends in Research and Patents Across Nutrition Targets (2022–2025)

Research, patents, and commercial implementation do not always align — and that misalignment reveals where the sector can move faster together.

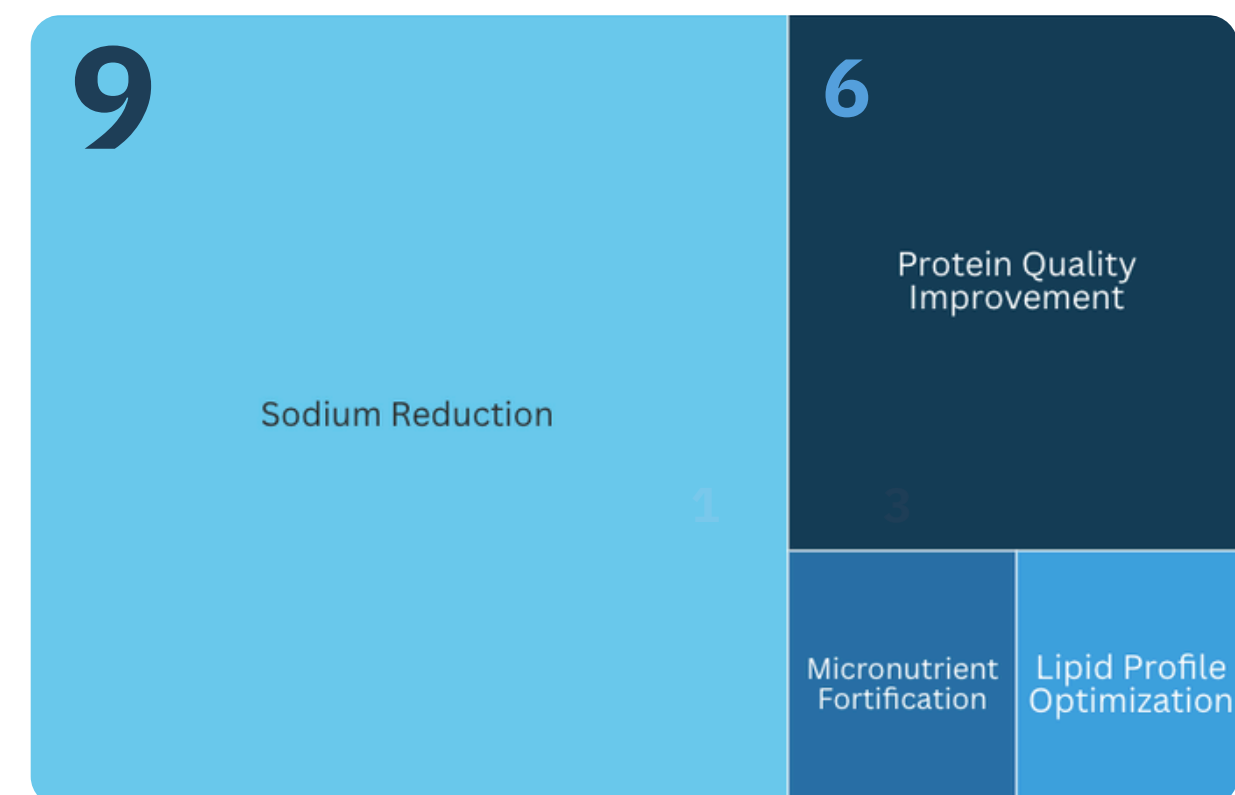
- Protein quality has high scientific attention and commercial adoption, but relatively fewer protectable innovations — reflecting its maturity and strong market pull.
- Sodium reduction, despite being the most patented area, is rarely a visible product focus — suggesting friction between technical feasibility, consumer priorities, and brand positioning.
- Micronutrient delivery and anti-nutrient reduction remain under-addressed across all stages — pointing to significant opportunity for targeted R&D and cross-sector partnerships.

“Protein quality dominates academic attention, while sodium reduction leads patent activity — other areas show whitespace.”

Research journals landscape



Patent landscape



A Systematic Framework for Characterizing Nutrition-Focused Innovation

This approach combines structured data curation, technology mapping, and expert validation to trace how formulation and processing innovations in plant-based meat address five core nutritional challenges. Parallely, a SWOC analysis distilled key insights from this process, identifying barriers and opportunities shaping the future of nutrition-forward innovation. Duration of study : December 2024 - Feb 2025)

Anchoring the Entire Study Around

Five Nutritional Imperatives:

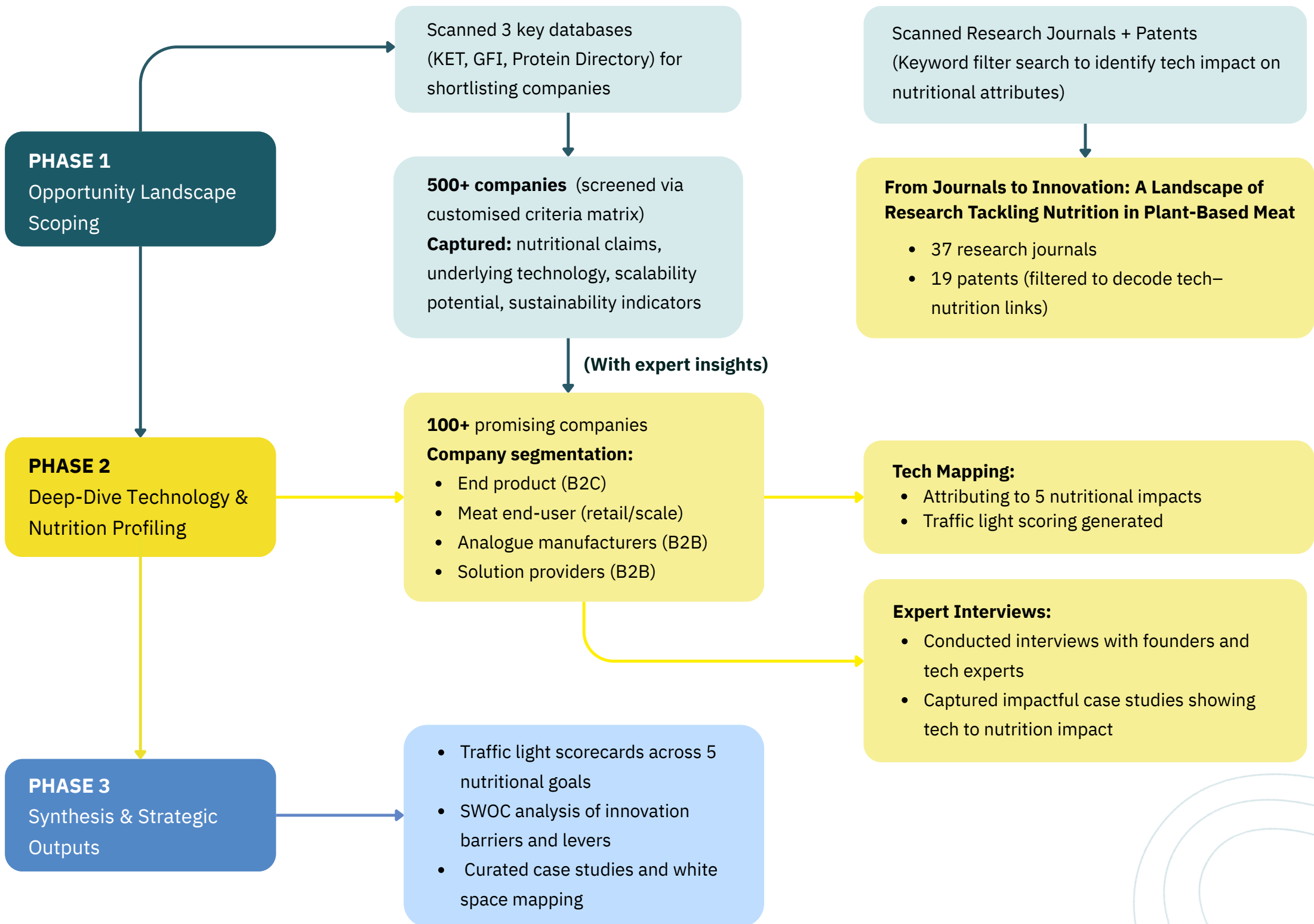
- Sodium reduction
- Lipid optimisation
- Protein quality improvement
- Micronutrient enhancement
- Antinutrient reduction

This systematic approach not only maps where the industry stands today, but also highlight where innovation can most meaningfully advance the nutritional profile of plant-based meat. The SWOC analysis reinforces the urgency—and opportunity—for science-backed, consumer-relevant solutions tailored to regional needs.

Study Duration: December 2024 – March 2025

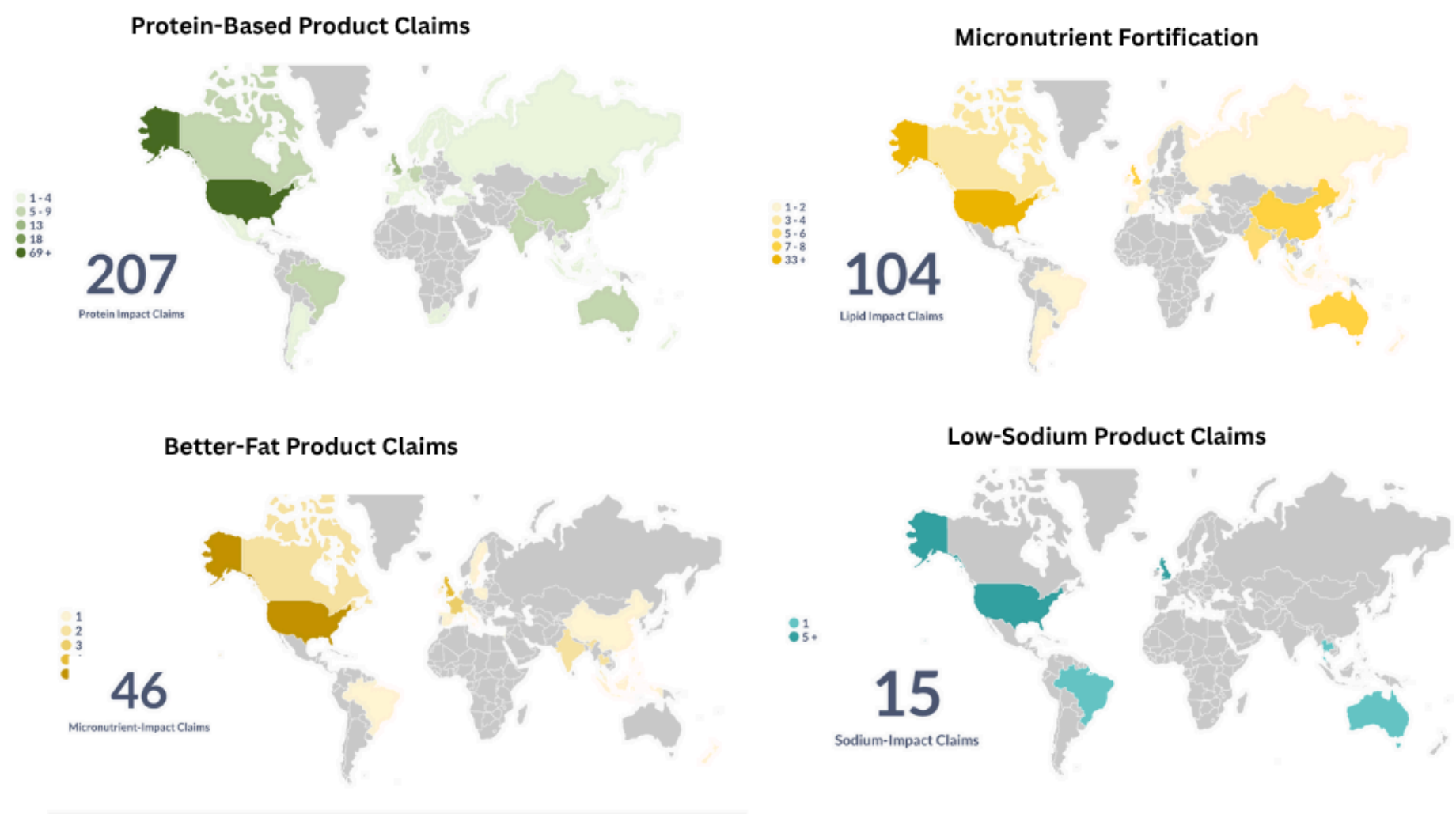
Please note that this landscaping study reflects data collected during this period. While we’ve made efforts to ensure accuracy, several developments have occurred between April and July 2025, including new fundraising rounds, company closures, and the emergence of new startups.

Disclaimer: Only selected developments from this post-study period have been included—primarily where we had the opportunity to directly interact with founders or verify updates. Companies or events that emerged outside our interaction scope have not been comprehensively covered.



Protein-Related Claims Lead Globally, but Gaps Remain in Other Nutrition Areas

This global snapshot shows how 462 companies are approaching core nutrition goals through product claims—spotlighting areas of momentum and opportunity.



Protein leads global nutrition claims in alt protein—while sodium, fat, and micronutrient innovation present critical whitespace opportunities.

Nutritional Claim Categories – Snapshot Guide

Protein-Based Product Claims

◆ Focus on enhancing essential amino acid profiles, improving digestibility, and developing novel protein structures (e.g., mycoprotein, precision-fermented proteins).

Low-Sodium Product Claims

◆ Innovations include umami enhancers, ingredient blends, or naturally low-sodium matrices to maintain flavor while cutting salt.

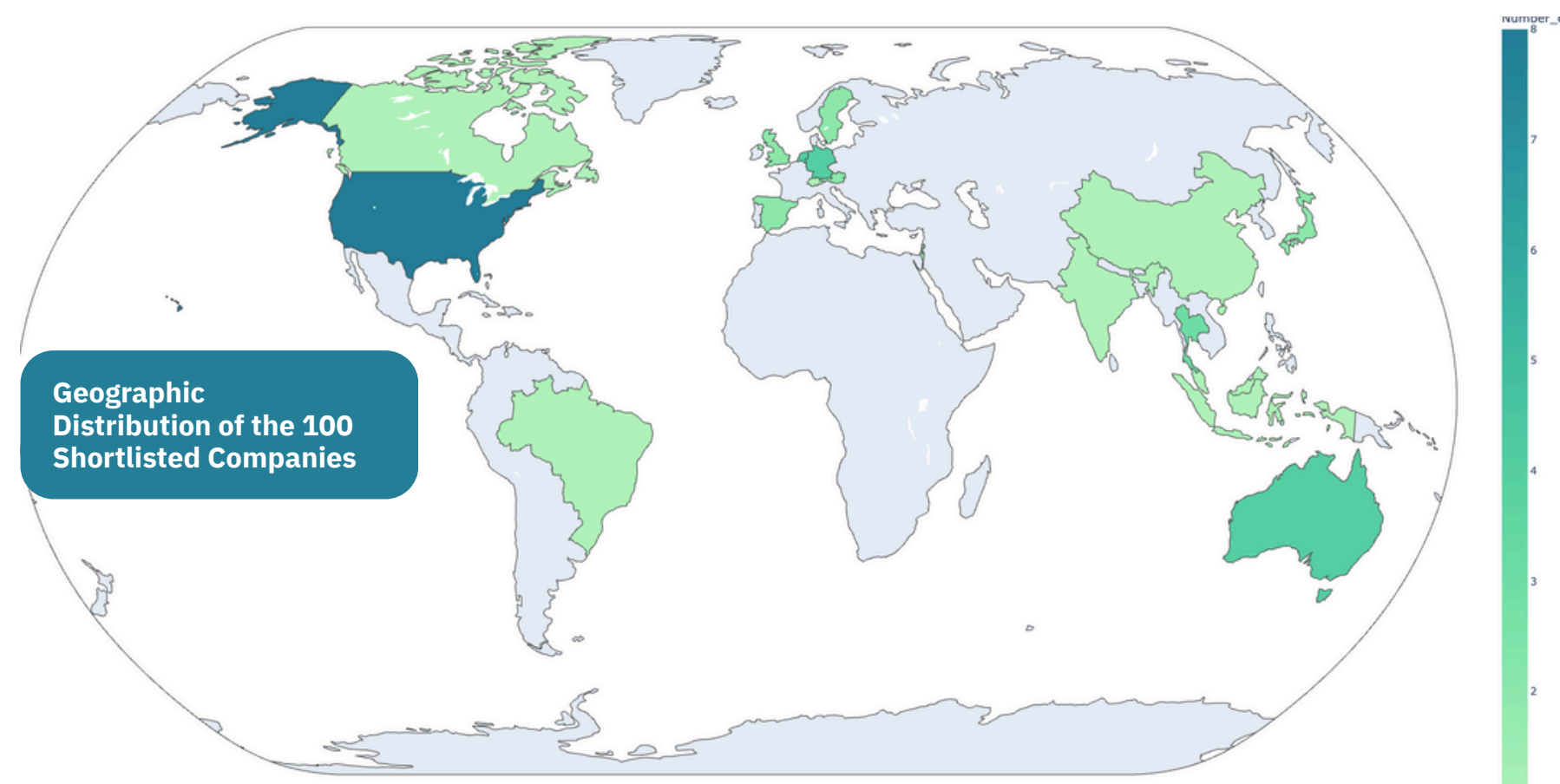
Micronutrient-Fortified Claims

◆ Centered on nutrients like Iron, Vitamin B12, Zinc, and B-complex vitamins—delivered via fortification or enhanced bioavailability.

Better-Fat Product Claims

◆ Linked to healthy lipid reformulation, such as algal oils, structured lipids, or reducing saturated fat content.

The data reveals a sharp imbalance: protein-related claims dominate, reflecting strong industry focus on quality and functionality. Meanwhile, sodium and lipid interventions remain rare, exposing clear whitespace. Micronutrient fortification is gaining ground but remains regionally uneven—likely shaped by policy and consumer preferences..



The featured companies are based across the U.S., Europe, Southeast Asia, and Israel—showcasing mature markets alongside fast-emerging innovation hubs in the nutrition-forward alt protein space.

How We Identified Key Innovators

This analysis spotlights 100 pioneering companies driving nutrition-forward innovation in plant-based meat. These players were selected based on their contributions to:

- ▶ Ingredient functionality (e.g., nutrient density, bioavailability)
- ▶ Processing innovations (e.g., fermentation, encapsulation, structuring)
- ▶ Product-level nutrition claims backed by formulation advances

Spanning the entire value chain—from upstream ingredient developers to consumer-facing brands—this curated group reflects the diversity of approaches shaping the next generation of nutritionally optimized alternative proteins.

Shortlisted companies

- Selected for impact on five nutrition priorities
- Includes B2C brands and B2B ingredient/tech providers
- Represent both input (ingredient) and process (technique) innovations
- Examples: Mycelium, algae, umami bases, micronutrient blends, structured lipids

Nutrition Innovation Within and Beyond Core Production Platforms

Extrusion and fermentation are foundational to alternative protein production—and key focal points for nutritional innovation. Many companies are enhancing these platforms to improve protein quality, reduce sodium, and increase micronutrient density.

Process Innovations:

- Enzymatic treatments,
- Targeted fermentation, Encapsulation,
- Novel structuring method to boost protein bioavailability, micronutrient content, and sodium perception.

Input Innovations:

- Nutrient-rich, functional ingredients (mycelium, algae)
- Low-sodium bases,
- Fortified protein blends

Meanwhile, emerging technologies—such as shear-cell processing, 3D printing, and directional freezing—are also being leveraged to enhance nutritional outcomes across diverse processing methods.

How We Categorized the Shortlisted Companies

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To better understand how each company contributes to nutrition innovation, we segmented the 100+ shortlisted players into two broad categories

B2C – Business-to-Consumer

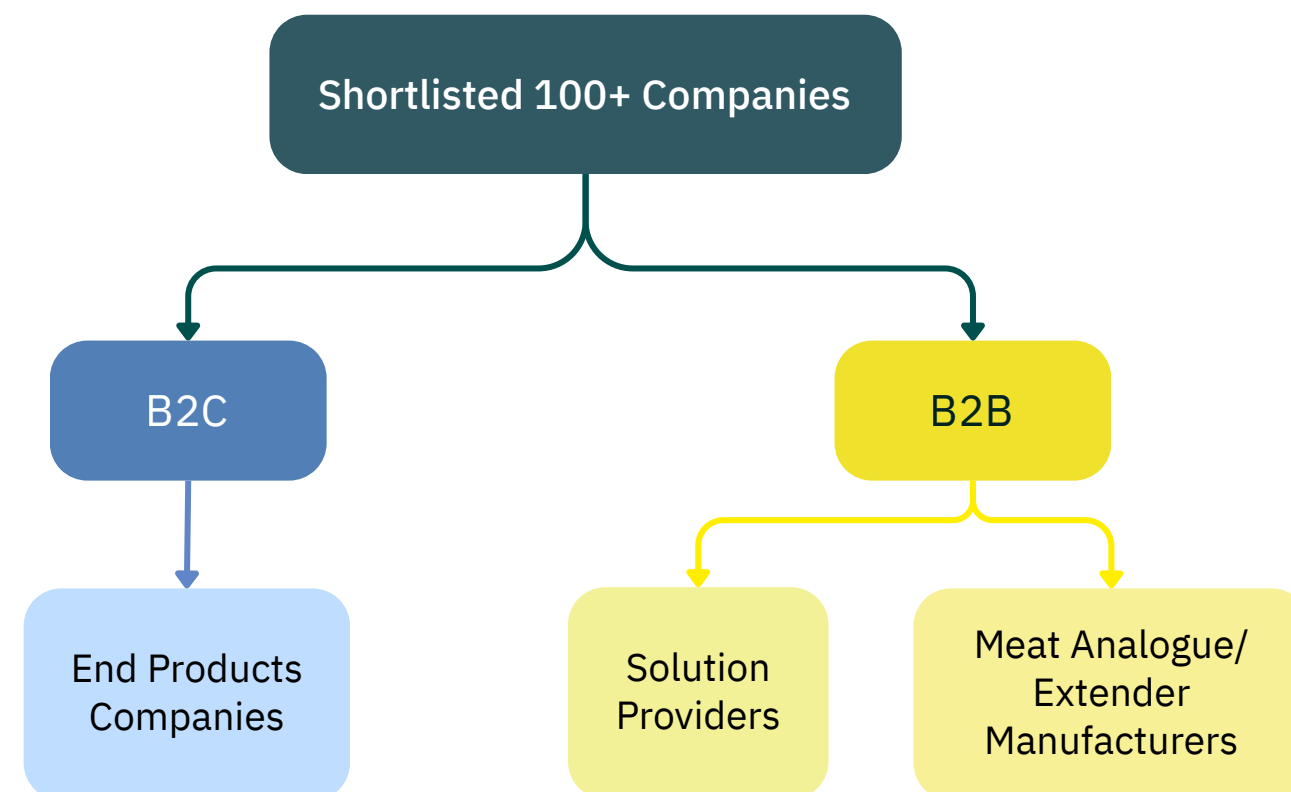
Companies that develop and sell branded end products directly to consumers. These players typically focus on taste, convenience, and health-positioned claims. Examples: Plant-based meat brands, ready-to-eat alt protein meals, functional nutrition SKUs.

B2B – Business-to-Business

Technology and ingredient suppliers that power the development and nutritional optimization of plant-based meat across the value chain.

Subcategories include:

- Solution providers: Specializing in processing technologies such as fermentation, encapsulation, or structuring methods
- Meat analogue/extender manufacturers: Supplying textured proteins, base matrices, or co-manufactured solutions








What This Segment Explores

- How companies deploy input and process innovations
- The impact of these strategies across five core nutrition goals:
 - Protein quality → Sodium reduction → Micronutrient fortification → Lipid profile optimization → Anti-nutrient factor reduction
- Key differences between B2C and B2B strategies in terms of maturity, market readiness, and depth of innovation

Targeting Nutrition Outcomes: How Process and Input Innovations Are Driving Progress

A snapshot of how companies are advancing five nutrition priorities—sodium, protein, fat, micronutrients, and antinutrients—through input and process innovation

Up Next: Explore the mechanisms, technologies, and leading company examples behind each nutritional innovation trend.

Notable Strategies Adopted by 100+ Companies to Enhance Nutrition		 Sodium Reduction	 Protein Quality Improvement	 Lipid Optimisation	 Micronutrient Enhancement	 Anti-Nutrient Reduction
Input Innovations	Process Innovations	<ul style="list-style-type: none">• Use of naturally low-sodium ingredients (e.g., fungi, jackfruit, seaweed)• Flavor enhancers (e.g., yeast extracts, umami compounds) to boost saltiness perception• Salt substitutes (e.g., potassium chloride)	<ul style="list-style-type: none">• Use of complete protein sources (e.g., soy, pea, mycoprotein, microalgae)• Complementary protein blending (e.g., pea + chickpea or legume + fungi)	<ul style="list-style-type: none">• Use of unsaturated, cholesterol-free oils (e.g., canola, rice bran, algal oils)• Use of low-fat base ingredients (e.g., oyster mushrooms, jackfruit)	<ul style="list-style-type: none">• Use of naturally rich ingredients (e.g., algae, fungi, legumes) for B12, iron, zinc, etc.	<ul style="list-style-type: none">• Use of low-antinutrient ingredients (e.g., fungi, blended bases)
		<ul style="list-style-type: none">• Fermentation and enzymatic treatments to enhance taste without added salt• Proprietary flavor systems (e.g., ClearTaste®, Springer® Umami) enabling 20–50% sodium reduction	<ul style="list-style-type: none">• Enzymatic hydrolysis (e.g., proteases) to release bio available peptides• High-moisture extrusion and 3D printing to align protein structures and improve absorption• Fermentation to enhance amino acid availability and digestibility• Germination to activate natural proteolytic enzymes	<ul style="list-style-type: none">• Microencapsulation and emulsions for controlled fat delivery and nutrient retention• Fermentation to stabilize fat integration and reduce oxidation• Structured fat systems (e.g., Mycolexin™, OleoPro™) to mimic animal fat with lower saturated fat	<ul style="list-style-type: none">• Direct fortification of iron, B12, iron, zinc, and omega-3s• Encapsulation to protect heat-sensitive vitamins and enzymes during processing• Fermentation to enhance mineral bioavailability (via phytate degradation)	<ul style="list-style-type: none">• Enzymatic treatments (e.g., phytase, protease) to break down anti-nutrients• Germination to reduce anti-nutritional factors and improve amino acid profile• Extrusion and shear processing to lower phytates and improve protein digestibility• Fermentation to degrade phytates, lectins, and trypsin inhibitors

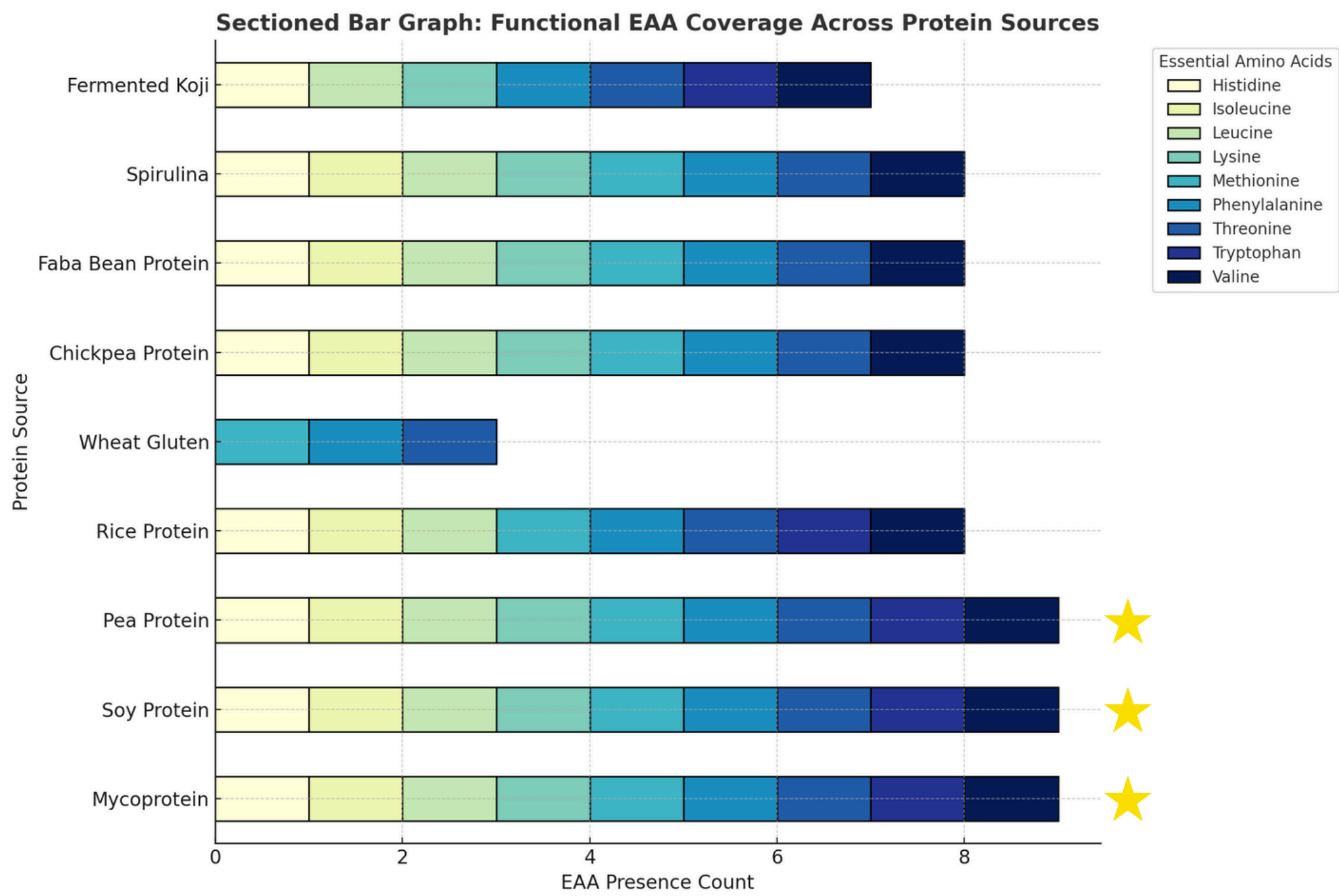
What Makes a High-Quality Protein?



Not All Plant Proteins Are Equal: Mapping Essential Amino Acid Profile

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This graph illustrates the presence of all nine essential amino acids (EAAs) across major plant-based protein sources, considering not just trace presence, but functional adequacy based on known limiting amino acids.



- Key Insights:**
- ✦ Mycoprotein, soy, and pea proteins stand out as functionally complete, meeting all 9 essential amino acid (EAA) thresholds.
 - ✦ Rice protein, while chemically complete, falls short due to low lysine levels—underscoring that adequacy matters as much as presence.
 - ✦ Wheat gluten covers only 3 of 9 EAAs, reinforcing the need for strategic blending with legumes.
 - ✦ Chickpea and faba bean proteins are nearly complete (8/9), typically limited by methionine, and benefit from pairing with cereals.
 - ✦ Fermented koji and spirulina show potential but require further study or complementary blending to achieve full profiles.

Soy and Mycoprotein Demonstrate the Most Comprehensive Nutritional Profiles

This sunburst visual showcases how leading plant-based ingredients stack up across three critical nutrition priorities:

- Digestibility (Cyan)
- Bioavailability (Yellow)
- Complete Protein Profile (Blue)

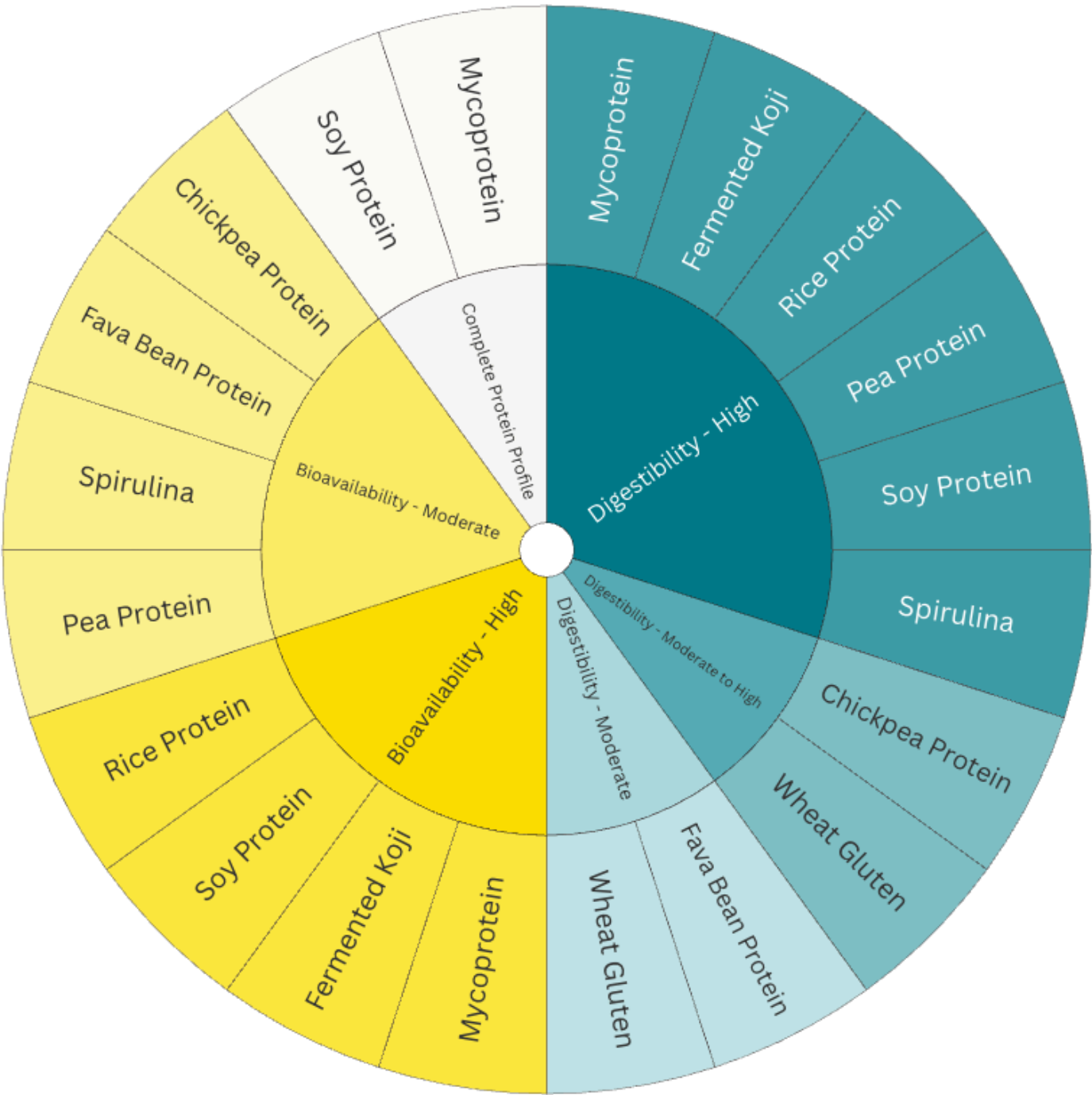
Each color gradient reflects performance:

- Darker = High, Lighter = Moderate

Each protein appears multiple times — once in each attributes

- The outside ring list out protein sources
- The inside ring represents level of digestibility, bioavailability or completeness of amino acid profile

Proteins that show high digestibility and bioavailability and a complete amino acid profile are consider high quality proteins



Key Takeaways

★ Mycoprotein

Appears across all three categories—offering exceptional digestibility, rich micronutrient bioavailability, and a complete amino acid profile. A standout multi-functional ingredient.

★ Fermented Koji

Featured for its high digestibility and bioavailability. Fermentation enhances nutrient absorption while improving texture and flavor.

★ Spirulina

Known for its high protein content and digestibility, with added benefits from its micronutrient density.

★ Soy & Pea Protein

Widely used for their versatility—showing up under all three metrics, though performance varies by processing method.

★ Wheat Gluten & Fava Bean Protein

Scored moderately in digestibility but provide value when combined strategically with complementary proteins.

Why This Matters

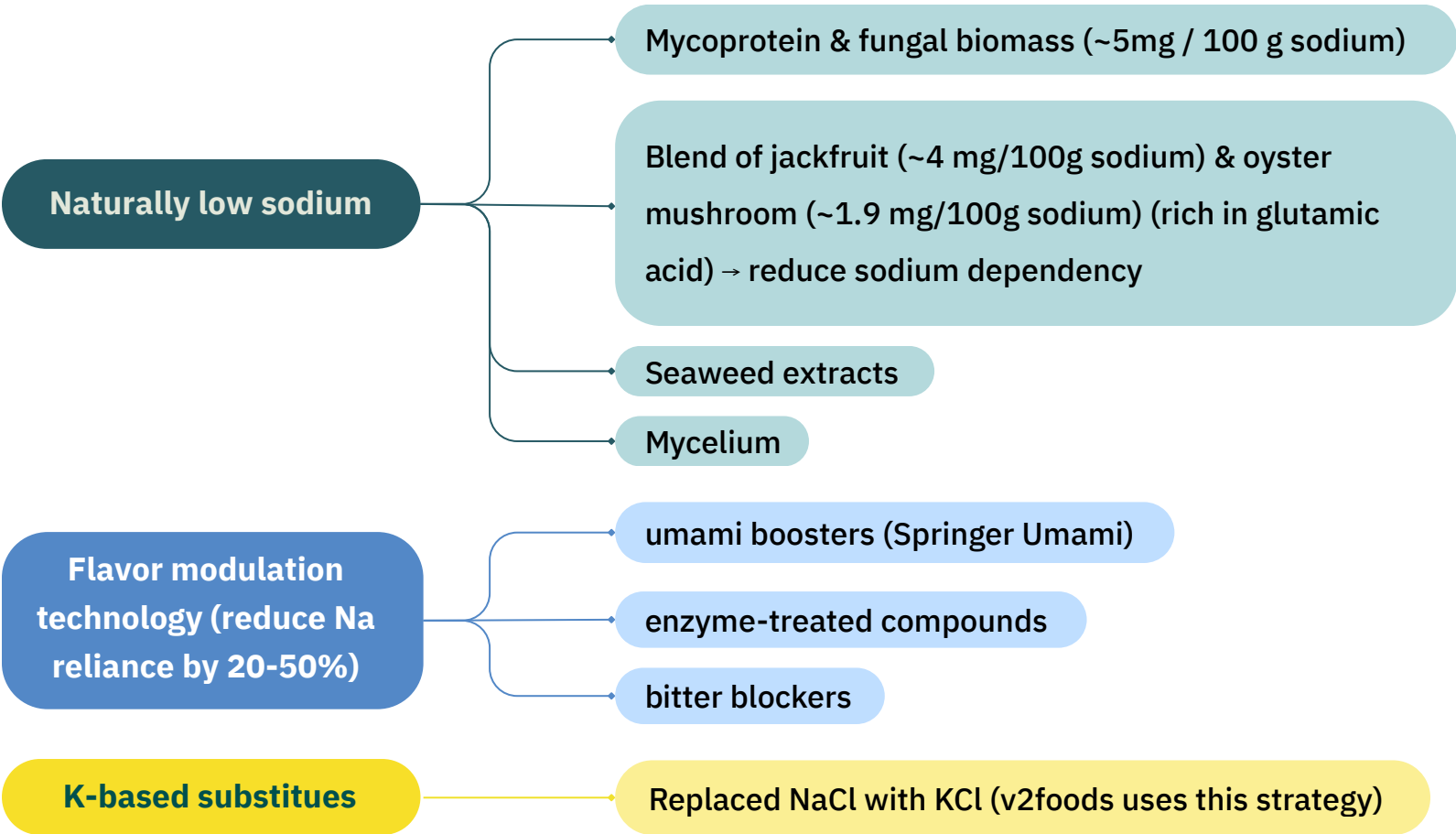
Protein quality remains a key challenge in plant-based meat. This visualization helps identify ingredients that do more than just add protein—they enhance absorption, bio-functionality, and completeness, making them essential to next-gen product formulations.

Reducing Sodium Through Ingredient Selection and Smarter Formulation

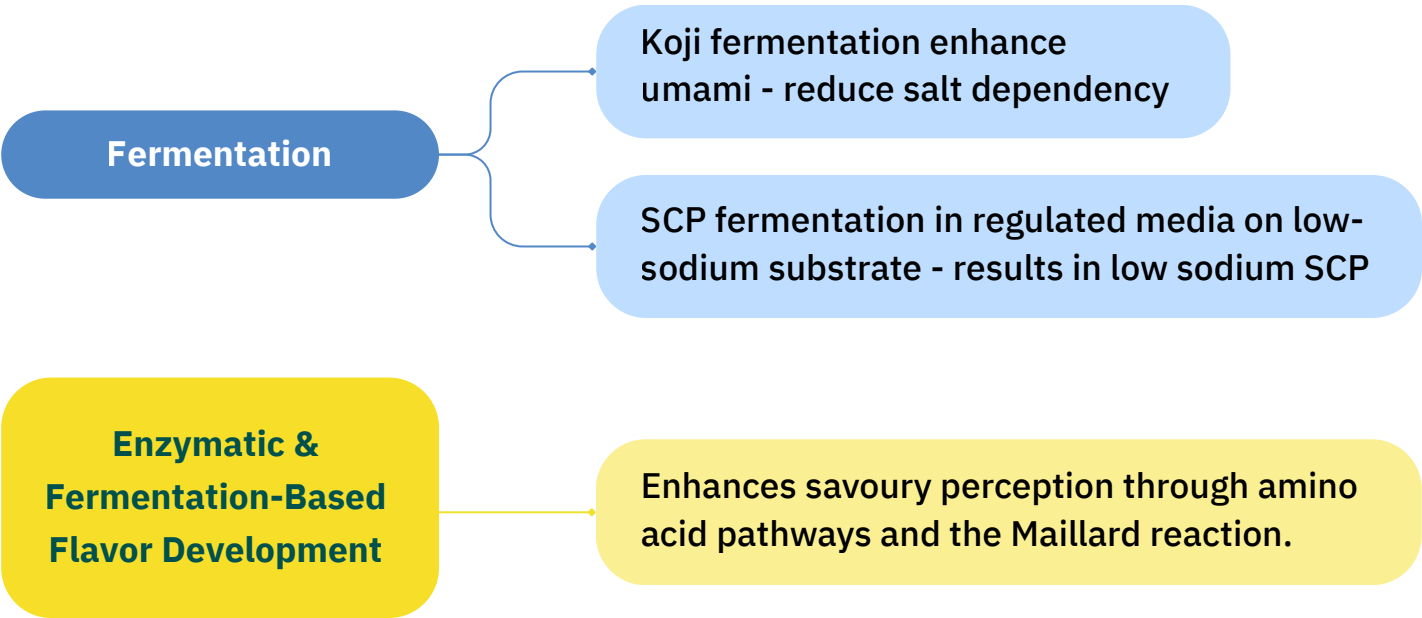
Why Sodium Matters—And Why the Next Generation of Innovation Rethinks It

Sodium isn't just a seasoning—it plays a critical role in plant-based meat production by amplifying umami, masking off-notes (especially in pea and soy), enhancing structure, supporting browning, and stabilizing texture. But while it's functional, excessive sodium poses nutritional challenges. That's why innovators are developing smarter ways to reduce sodium dependency—through strategic ingredient selection and processing techniques that preserve function without compromising flavor or texture.

Input Innovations



Process Innovations



Implications for Low-Sodium Product Design

✦ Rice protein is gaining traction as a lower-sodium base that, when blended with pea or soy, can:




Maintain structural integrity during extrusion | Enhance natural flavor without masking agents | Support moisture retention and clean-label claims

✦ These strategies reflect a broader trend toward intelligent protein pairing and precision processing to deliver better nutrition with less salt.

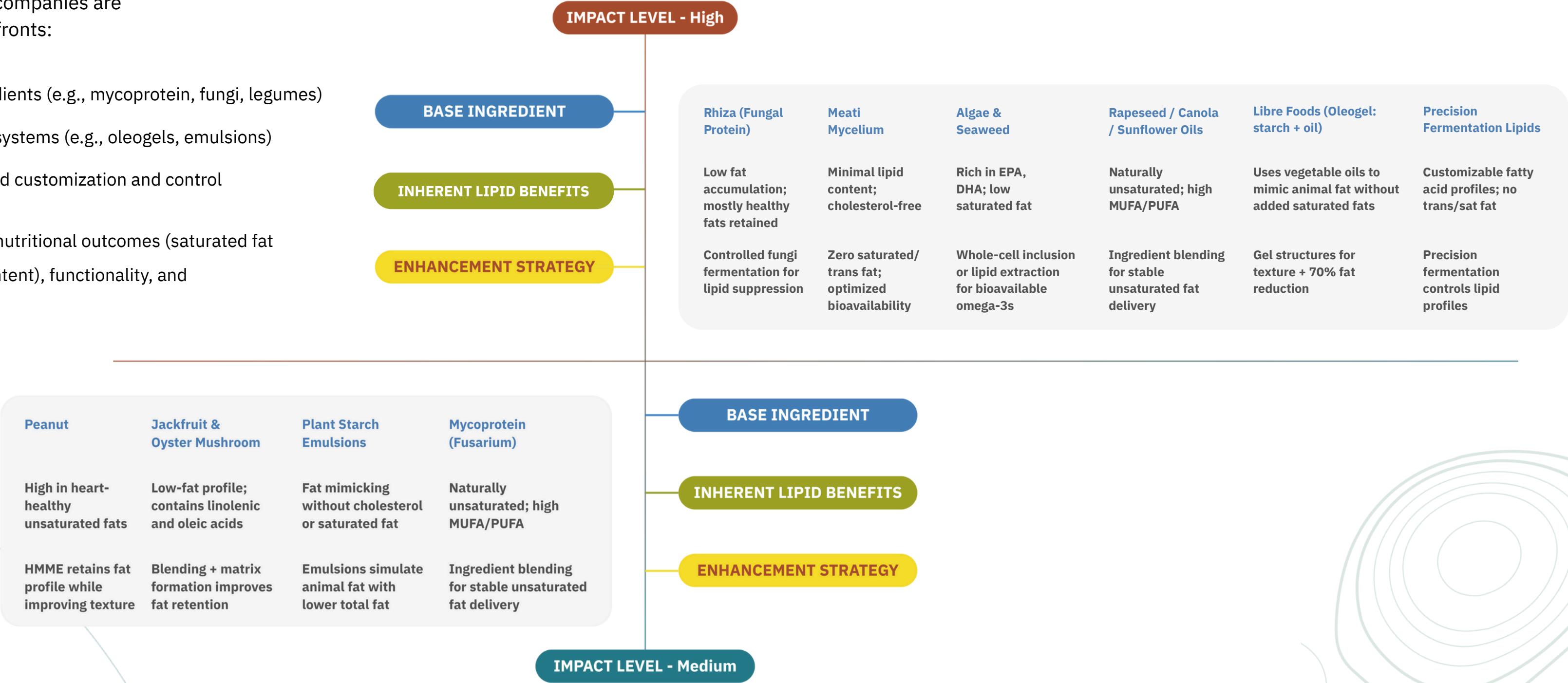
Optimizing Lipids in Plant-Based Meat: Balancing Health, Flavor, and Functionality

While plant-based meats offer clear sustainability and animal welfare benefits, rethinking fat is key to nutritional progress. Unlike animal fats, plant lipids must achieve taste, texture, and functionality with minimal saturated or trans fats.

To meet this challenge, companies are innovating across three fronts:

-  Healthier base ingredients (e.g., mycoprotein, fungi, legumes)
-  Smarter fat delivery systems (e.g., oleogels, emulsions)
-  Fermentation-led lipid customization and control

Impact tiers are based on nutritional outcomes (saturated fat reduction, healthy lipid content), functionality, and commercial maturity.



Fermentation, Structuring, and Oil Selection Are Driving Lipid Innovation

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Lipid Optimization Methods



Ingredient-Level – Use of mycoprotein (Rhiza, Meati), fungi, jackfruit, rapeseed oil, algal oils



Fat Structuring – Oleogels, starch emulsions, hydrogel systems, oil layering (e.g., Juicy Marbles)



Fermentation & Processing – Precision and fungal fermentation, germination, extrusion to shift lipid profiles and improve absorption

Lipid Innovation: What's Working & What's Next - Key Takeaways



Diverse Approaches, Shared Goal

From base ingredients to engineered fats, companies are converging on heart-healthier, animal-fat-like profiles—without relying on trans or saturated fats.



Whole-Cell Fermentation & Fungal Lipid Control

Platforms like Rhiza and Meati use cell-level lipid tuning to minimize saturated fat and optimize nutrition at the source.



Structured Fats Deliver Function with Fewer Downsides

Oleogels, microencapsulation, and blended plant oils (e.g., Libre, canola) offer clean-label solutions with controlled melt, mouthfeel, and cholesterol-free appeal.



Precision Fermentation Powers Customization

Tailored fatty acid profiles are emerging via PF—opening new doors for targeted nutrition and functional performance.



Emerging White Spaces

Opportunities remain in scaling low-cost, solid fat mimetics and improving omega-3 bioavailability in plant-based applications.

Closing the Micronutrient Gap Through Fortification and Bioavailability

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Micronutrients like iron, zinc, B12, and vitamin D are critical to human health — yet they are often underrepresented or poorly absorbed in plant-based meat. These nutrients are not only vital for physiological function but also for replicating the nutritional quality of conventional meat, influencing aspects like color, mouthfeel, and metabolic benefit. In plant-based meat, companies are moving beyond passive addition of nutrients. There is a growing shift toward precision strategies that ensure micronutrients are not just present, but also bioavailable, stable, and synergistically effective.

Key Methods Companies Are Using:

1. Ingredient Blending & Targeted Additions

Inclusion of nutrient-rich ingredients like moringa extract, leghemoglobin, and algal oil (for omega-3s). Use of naturally rich sources like oyster mushroom, microalgae, lupin, and SCPs for intrinsic micronutrients (e.g., B12, iron, zinc, vitamin E).

2. Nutrient Fortification

Addition of isolated nutrients such as ferrous sulfate, ascorbic acid (to boost iron absorption), or vitamin D, directly into formulations. Fortification is often coupled with technologies like spray drying, emulsion stabilization, or encapsulation to protect sensitive nutrients.

3. Bioavailability-Enhancing Processes

Fermentation with strains like *Neurospora crassa*, *Bacillus subtilis*, or *Propionibacterium freudenreichii* to synthesise or activate B12, degrade phytates, and release bound minerals. Extrusion and shear processing to preserve or enhance the bioavailability of thermolabile micronutrients. Use of germination, enzymatic treatments, or even transgenic modifications to improve nutrient transport and uptake (e.g., enhancing heme-binding proteins).

The following slide maps how a diverse set of ingredients — from fungi and legumes to single-cell proteins — are being paired with these strategies to unlock meaningful gains in micronutrient quality, bioavailability, and health functionality.

Fungi, Algae, and Fermentation Are Enabling Next-Gen Fortification

Micronutrient delivery in plant-based meat is no longer just about adding vitamins and minerals. Today, it’s about activating them—making sure they are absorbed, retained, and biofunctional in the body.

This shift is powered by fungi, algae, and microbial fermentation—biotechnologies that don’t just carry micronutrients but unlock and enhance their potency. From precision-engineered strains that synthesize B12 to fermentation strategies that break down absorption-blocking antinutrients, we're seeing a transformation in how nutrition is designed into the food system. By mapping fortification strategies by nutrient—not ingredient—we uncover new levers to fill critical dietary gaps, especially in vegan and flexitarian diets.

Iron (Fe)

- Sources: Fermented soy, Leghemoglobin, *Fusarium* sp., SCP, Oyster & Shiitake mushrooms
- Enhancement Approaches:
 - Heme iron mimics (e.g., leghemoglobin)
 - Fermentation with Koji, Shiitake for improved mineral uptake
 - Enzymatic degradation of phytates for better absorption
- Why It Matters: Iron deficiency is widespread; innovations offer better forms with high absorption.

Vitamin B12

- Sources: Microalgae, Lupin (with *Propionibacterium*), Soy (via SSF), SCP
- Enhancement Approaches:
 - Solid-state fermentation (SSF) boosts B12 up to 1230 ng/g in lupin
 - Engineered microbes & single-cell strains tailored to synthesize B12
- Why It Matters: B12 is nearly absent in plant sources; critical gap-filler in vegan diets.

Zinc & Copper

- Sources: Yeast (*Saccharomyces*), *Fusarium*, SCP
- Enhancement Approaches:
 - Tailored fermentation improves mineral retention
 - Yeast extract systems for direct fortification
- Why It Matters: Supports immune and metabolic functions; often under-consumed.

Iodine & Omega-3s (DHA/EPA)

- Sources: Microalgae
- Enhancement Approaches:
 - Whole biomass or extracts for better absorption
 - Used in base formulations for marine-based micronutrient enrichment
- Why It Matters: Hard-to-source nutrients for vegans; crucial for brain & thyroid function.

Selenium & Antioxidants

- Sources: Shiitake, Oyster Mushrooms
- Enhancement Approaches:
 - Mushroom fermentation enriches antioxidant load (ergothioneine, β -glucans)
 - Natural B-vitamin preservation through controlled fermentation
- Why It Matters: Combats oxidative stress; supports cellular protection.

Key Takeaways

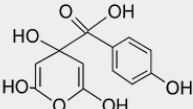
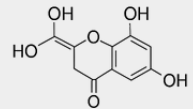
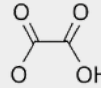
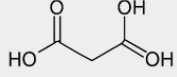

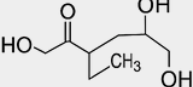

- ✳ **Bioavailability Is the New Benchmark**
It’s not about whether a nutrient is present—but how well it’s absorbed and utilized by the body.
- ✳ **Fermentation = Fortification 2.0**
Fungal and microbial systems go beyond enrichment—they unlock, synthesize, and stabilize micronutrients.
- ✳ **B12 Is Getting a Breakthrough**
Novel fermentation (e.g., *Propionibacterium* with lupin or soy) delivers reliable B12 levels in plant matrices.
- ✳ **Functional Fungi and Algae Are Unsung Heroes**
Mushrooms, *Fusarium*, and microalgae quietly address iron, selenium, omega-3s, and more—naturally.
- ✳ **Toward Precision Nutrition in Alt Protein**
Engineered SCP and yeast strains offer customizable nutrient profiles, matching specific health outcomes.

Micronutrient innovation is evolving from simple fortification to precision delivery systems using fungi, algae, and microbial fermentation — ensuring nutrients are:

- More bioavailable
- Better retained post-processing
- Matched to consumer health needs

Reducing Anti-Nutrients to Enhance Mineral and Protein Absorption20

Anti-nutrients like phytates, lectins, and protease inhibitors are common in plant-based protein sources. While common, they can impair the absorption of key minerals such as iron, zinc, and calcium, and reduce overall protein digestibility. This table highlights the primary anti-nutritional compounds, their impact on nutrient bioavailability, and the mitigation strategies, ranging from enzymatic treatments, fermentation to extrusion and germination. These approaches are playing an increasing role in enhancing the nutritional quality of next-generation alternative proteins.

Anti-Nutrient	Chemical structure	Impact on Nutrient Absorption	Technology	Anti-Nutrient Impact	Impact of Technology on Antinutrient Reduction
Phytate (Phytic Acid)		Binds essential minerals like iron, zinc, calcium, and magnesium, reducing their bioavailability.	Hydrolysis	Medium	Enzymatically breaks down phytic acid and protease inhibitors - Improves protein digestibility and mineral absorption - Highly effective when enzyme-specific conditions are met
Tannins		Bind to proteins and minerals, decreasing protein digestibility and mineral absorption.	Fermentation	Medium to High	Microbial activity reduces phytic acid and protease inhibitors - Example: Shiitake-fermented pea-rice blend shows ~50% phytic acid reduction
Oxalates		Form insoluble complexes with calcium, reducing its absorption.	Extraction	Medium to High	Aqueous: removes tannins and saponins - Salt-based: reduces lectins and phytic acid - Solvent: targets saponins and phenolics - Membrane: removes small inhibitors - Enzymatic: breaks down phytates and protease inhibitors
Lectins		Can impair nutrient absorption and damage the intestinal lining.	Extrusion	High	Deactivates trypsin inhibitors, lectins, and phytic acid - Enhances protein digestibility and reduces flatulence-causing oligosaccharides
Trypsin Inhibitors		Inhibit digestive enzymes like trypsin, limiting protein breakdown and absorption.	Ochiai Germination Method	High	Activates natural enzymes during sprouting - Reduces trypsin inhibitors, lectins, and phytic acid - Boosts digestibility and mineral absorption
Saponins		Disrupt nutrient transport and affect gut health.	Spray Drying + Fermentation	High	Fermentation reduces phytic acid, lectins, and inhibitors - Spray drying stabilizes and preserves nutrient benefits - Suitable for high-functionality powders
Protease Inhibitors		Inhibits digestive enzymes, reduce protein digestion.			

Multiple Processing Strategies Support Antinutrient Reduction



This diagram illustrates how processing strategies—especially fermentation—help reduce key antinutrients in plant-based proteins, including phytates, tannins, oxalates, lectins, saponins, and protease inhibitors. While fermentation supports microbial degradation and enzyme activation (e.g., phytase), complementary techniques like soaking, germination, blanching, and cooking further reduce antinutrient content through leaching or denaturation. Together, these methods enhance mineral bioavailability, protein digestibility, and the overall nutritional quality of plant-based meat.

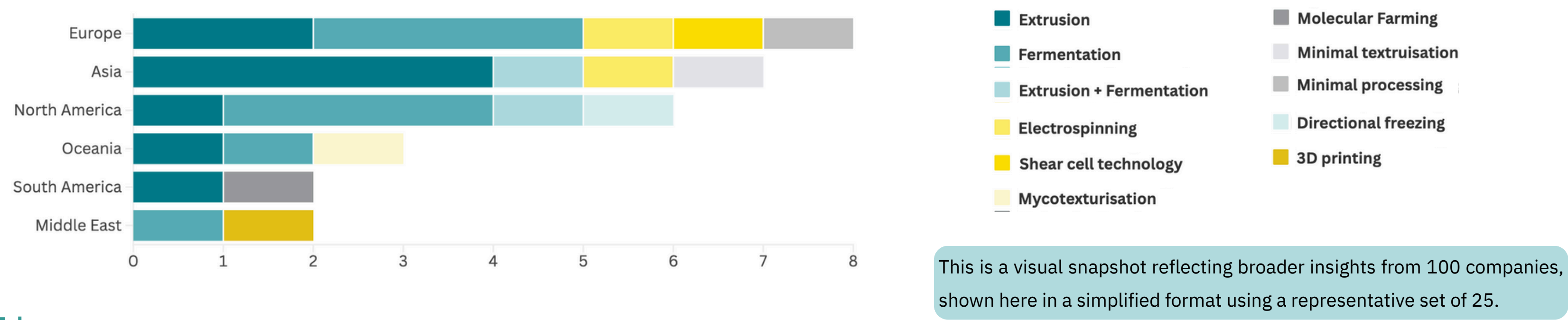
Fermentation stands out as a versatile, natural tool for reducing a broad spectrum of antinutrients—especially when integrated with soaking, germination, and other gentle processing techniques.

Mapping the Nutritional Impact of Alternative Protein Production Technologies

To assess how production technologies are contributing to nutritional improvements in plant-based meat, we began by mapping the core platforms used by the 100 companies in our analysis. These technologies—ranging from high-moisture extrusion in Europe to electrospinning and minimal texturization in Asia—reflect a dynamic mix of established and emerging approaches shaped by regional priorities and innovation ecosystems.

Importantly, nutrition outcomes are rarely the result of a single platform alone. Companies are layering targeted strategies—such as precision ingredient selection, microbial strain optimization, and process enhancements—to unlock added nutritional value. Fermentation, in particular, is being leveraged in diverse and sophisticated ways to boost micronutrient density, reduce anti-nutrients, and improve bioavailability.

The following heatmap provides a composite view of the nutritional impact associated with each platform. Scoring reflects not only the inherent potential of the technology, but also the supporting strategies applied—from base ingredient choices to input and process innovations. This integrated perspective highlights where validated nutritional benefits are emerging—and where untapped opportunities remain across five key nutrition goals.

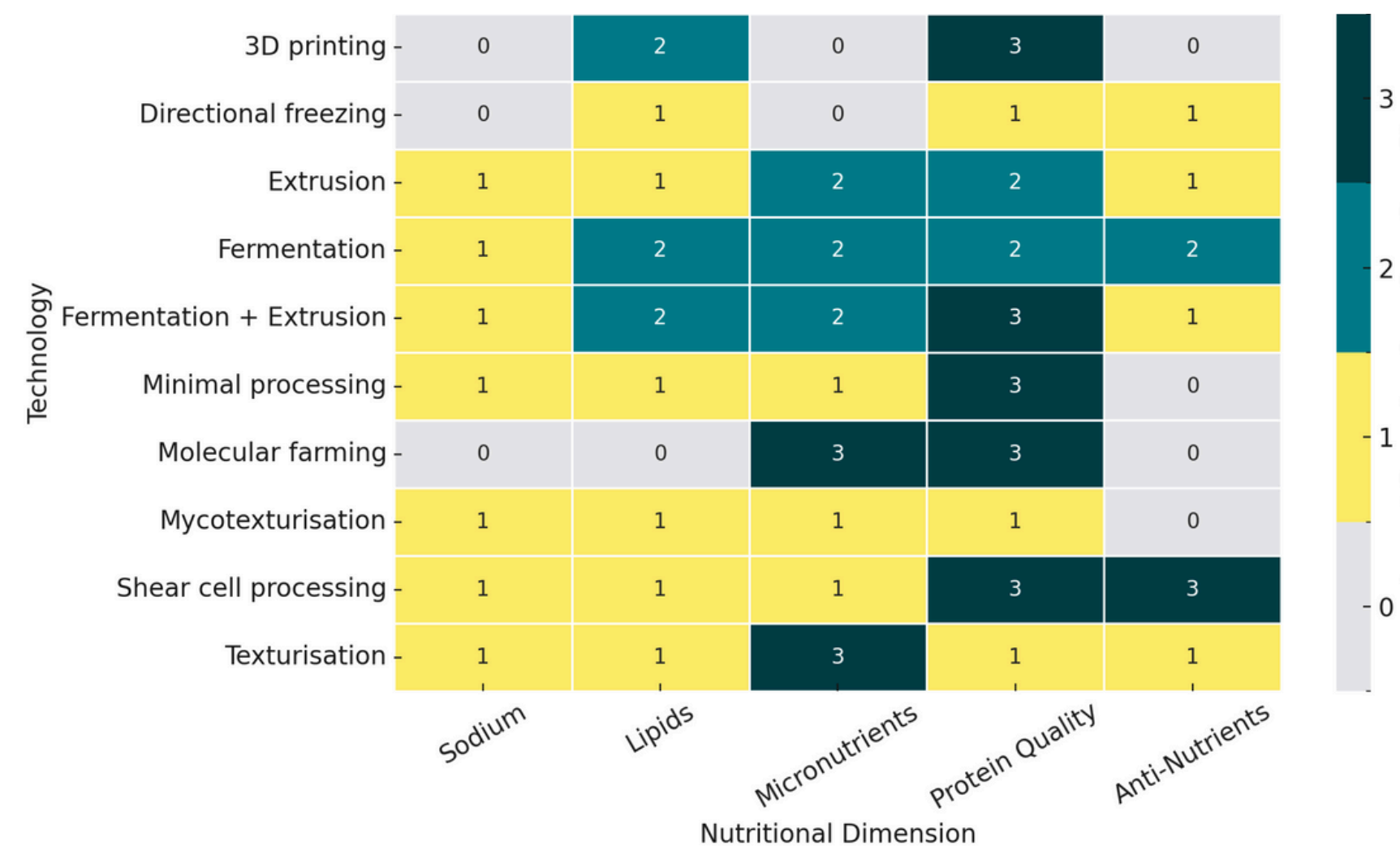


Key Takeaway:

This chart illustrates how regions are adopting a blend of established and emerging production technologies to meet evolving nutritional and processing goals.

- * **Europe** leads with the most diverse toolkit, reflecting a mature innovation ecosystem.
- * **Asia** shows strong uptake of extrusion and fermentation, alongside experimentation with novel methods like electrospinning.
- * **North America** balances established platforms with interest in next-gen approaches such as directional freezing.
- * **Emerging regions** are selectively adopting technologies aligned with local priorities, raw material availability, and market needs.

The distribution reflects not just technological capacity, but the nuanced ways regional ecosystems are advancing nutrition through tailored innovation strategies



This heatmap illustrates how production technologies contribute to five key nutrition goals—sodium reduction, lipid optimization, micronutrient delivery, protein quality, and anti-nutrient reduction. Scores reflect not just the core platform, but how it’s applied: base ingredients, process innovations, input selection, and in some cases, strain-level optimization (e.g., in fermentation).

Scoring scale:

- 3 = High impact
- 2 = Medium
- 1 = Low
- 0 = No evident impact

Fermentation and fermentation–extrusion emerge as the most consistently impactful, supporting multiple dimensions of nutrition. Directional freezing and mycotexturization show targeted potential, especially in lipids and micronutrients. Newer tools like 3D printing offer narrow but novel advantages.

This framework can guide R&D teams in selecting tech stacks based on nutritional targets—and identifying where white spaces remain.

Using This Map

- Targeting B12, zinc, or iron? → Start with fermentation or mycotexturization
- Need better fat profiles? → Explore directional freezing or structured oils
- Addressing anti-nutrient challenges? → Fermentation remains a top solution

Key Takeaways

- Fermentation consistently delivers across all five nutrition dimensions.
- Combine platforms (e.g., fermentation + extrusion) enhance multi-functional impact.
- Directional freezing and mycotexturization show promise in lipids and minerals.
- Lipid optimization remains a key opportunity area.
- Anti-nutrient reduction is still led by fermentation and enzymatic strategies.

How Production Processes Translate into Nutritional Outcomes

This section examines how core production technologies are being harnessed to improve nutrition in plant-based meat — beginning with extrusion and fermentation, the most widely adopted platforms in our mapping.

We unpack how these technologies contribute to nutritional outcomes through three key pathways: structural design, enzymatic enhancement, and strategic formulation. Their application is further illustrated through sunburst visuals and a comparative traffic light analysis that synthesizes their overall impact across five nutrition dimensions.

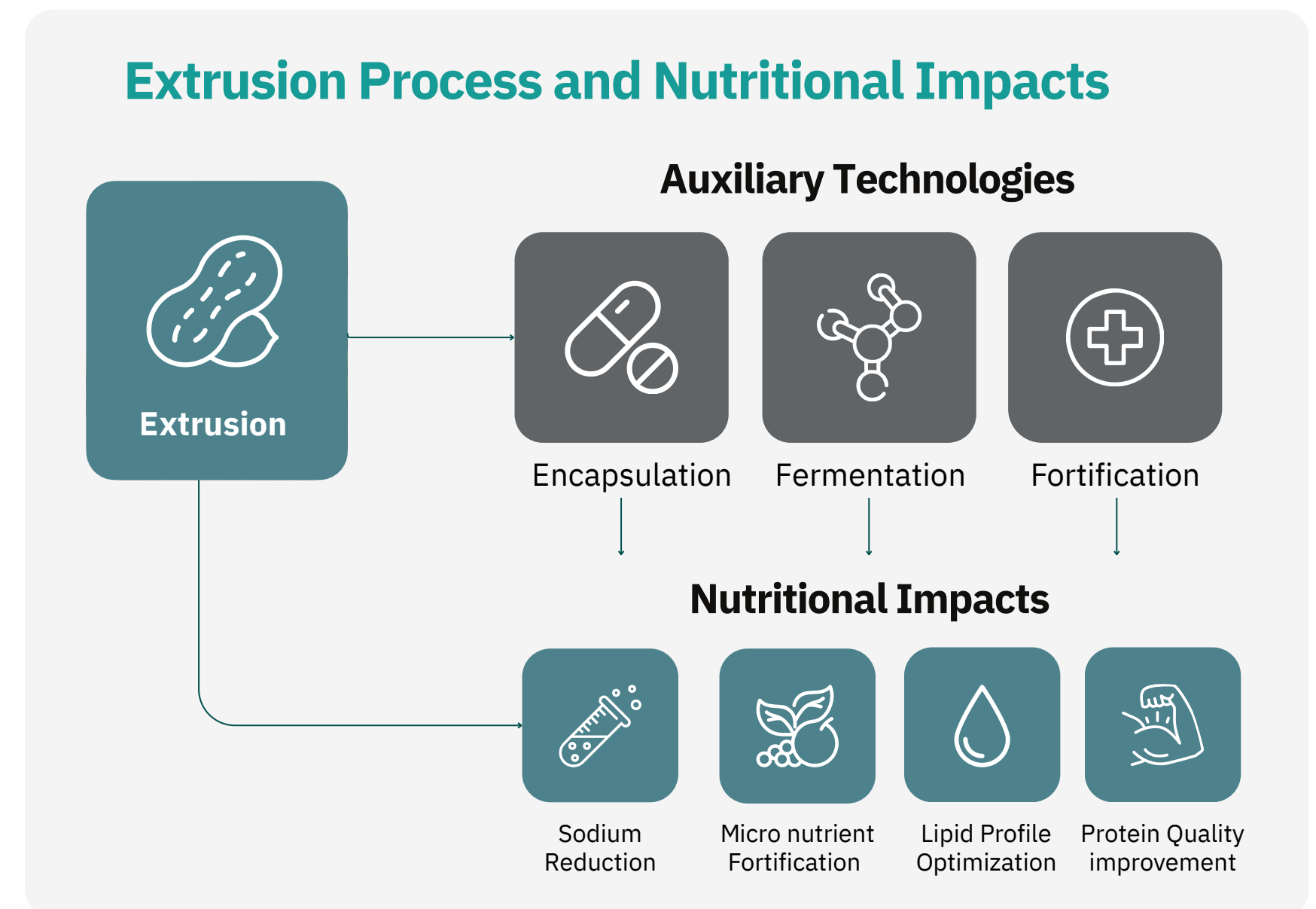
Extrusion Technologies and Their Role in Nutritional Innovation

Extrusion is one of the most scalable and widely used technologies in plant-based meat, particularly valued for its ability to create meat-like textures and structure proteins.

Our analysis reveals that nutritional improvements via extrusion are primarily achieved through:

- Strategic ingredient blending (e.g., pea + wheat) to enhance PDCAAS
- Processing parameters that help reduce anti-nutrients
- Post-extrusion fortification to boost micronutrient content

However, sodium and lipid optimization remain underexplored in extrusion applications — highlighting key opportunities for next-gen formulation strategies



Strategic Pairings for Nutritional Impact in Extrusion

Extrusion Technologies in Plant- Based Meat

Extrusion Technologies



Dry Extrusion



HMEC (High Moisture Extrusion)



Extrusion +
Fortification



Extrusion +
Fermentation

Key Ingredient



Soy



Pea



Wheat



Sunflower



Other

“Extrusion is more than a structuring tool — it’s increasingly being used to deliver targeted nutritional benefits across product types.”

High Moisture Extrusion (HME) is identified as the dominant method for AP

Strategy pairings that unlock specific nutrition benefits:

- HME + Fortification → iron & B12 delivery
- HME + Fermentation → improved anti-nutrient reduction and flavor
- Encapsulation → shields heat-sensitive nutrients during high-temperature processing
- Potassium-based salts → sodium reduction without taste compromise

Soy–pea blends are favored for both texture and amino acid completeness, reinforcing their importance in HME applications.

With extrusion offering a foundation for structural and micronutrient interventions, we now turn to fermentation — a platform increasingly used for functional enhancement, flavor, and bioavailability.

Fermentation Platforms Unlock Distinct Nutritional Advantages

26

Fermentation technologies used in plant-based meat typically fall into two categories: Liquid-State Fermentation (LSF) and Solid-State Fermentation (SSF). These formats differ in processing conditions, strain usage, and substrates, each offering unique benefits for nutritional enhancement.

Liquid-State Fermentation (LSF)

- Process: Submerged growth (aerobic or anaerobic) in liquid media
- Primary Functions:
 - Efficient biomass generation
 - Protein density enhancement
 - Amino acid tailoring
 - Lipid profile optimization
- Common Strains:
 - *Fusarium venenatum*
 - *Neurospora crassa*
- Typical Substrates:
 - Mycoprotein blends
 - Pea–rice protein
 - Acacia or oat fibers
 - Mushroom-based mixes

Solid-State Fermentation (SSF)

- Process: Surface or shallow-layer growth on solid materials
- Primary Functions:
 - Anti-nutrient reduction (e.g., phytates)
 - Enzyme activity for nutrient bioavailability
 - Textural enhancement
- Common Strains:
 - *Aspergillus oryzae*
 - *Pleurotus spp.*
- Typical Substrates:
 - Koji root
 - Soy–wheat matrices
 - Legumes (e.g., chickpea, mung bean)
 - Fungal biomass on solid substrates

The interplay of fermentation type, strain, and substrate shapes nutritional transformation—affecting everything from amino acid enhancement to mineral bioavailability and anti-nutrient breakdown.

Microbial Strain Selection Drives Nutrient Bioavailability and Functionality

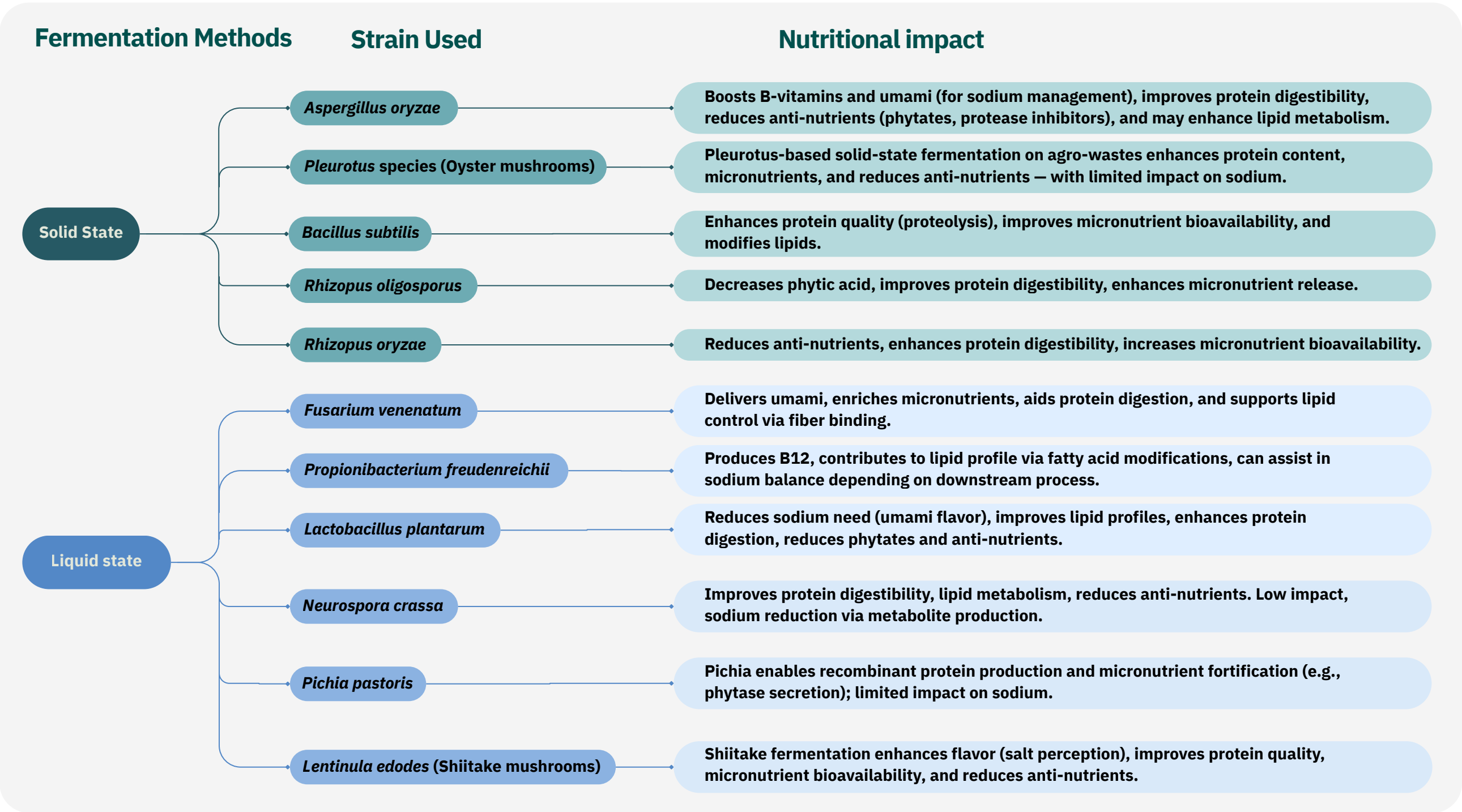
This map showcases how different fermentation approaches — and the microbial strains they employ — shape specific nutritional outcomes. From phytate degradation to B12 biosynthesis and lipid optimization, strain selection plays a pivotal role in unlocking the full nutritional potential of fermented ingredients.

Strain-Specific Nutritional Impacts Across Fermentation Methods

KEY INSIGHTS

- Solid-state fermentation strains (e.g., *Aspergillus*, *Pleurotus*) are particularly effective at reducing anti-nutrients and improving protein digestibility.
- Submerged strains such as *Fusarium* and *Propionibacterium* support micronutrient synthesis, enhance lipid metabolism, and enable sodium reduction through umami enhancement.
- Emerging strains like *Neurospora crassa* and *Pichia pastoris* show promise for multi-functional benefits—from vitamin biosynthesis to protein quality enhancement.

Nutritional outcomes depend on the right match between strain, substrate, and process—reinforcing the need for targeted formulation design.



From microbial transformation to mechanical restructuring, processing technologies play a pivotal role in enhancing the nutritional profile of plant-based meat. This section maps real-world company activity and innovation across three dominant processing categories—fermentation, extrusion, and other emerging technologies—against five key nutrition priorities identified by GFI:

- Protein quality, sodium reduction, lipid optimization, micronutrient fortification, and anti-nutrient reduction.
- Each sunburst visual quantifies the impact of these technologies by mechanism (input, process, or combined), offering a comparative view of their contribution to nutritional advancement.

Other Notable Technologies Covered:

Technology	Focus Area	Key Nutrition Impact
Shear Cell Processing	Structuring	Enhances umami, reduces saturated fat
3D Printing	Texturing	Sunflower oil marbling
Directional Freezing + Infusion	Delivery	Omega-3 embedding
Microencapsulation	Fortification	Micronutrient delivery, masks anti-nutrients
Proprietary Infusion	Flavor/Lipid	DHA/EPA fortification, sodium reduction
Spray Drying	Delivery	Stabilizes micronutrients
MicroForce (3D Printing)	Fat Structuring	Improves fat distribution

Not all technologies are equal.

- Fermentation excels in micronutrient bioavailability and anti-nutrient reduction
- Extrusion is strongest in protein restructuring and lipid embedding
- Emerging tech fill targeted gaps (e.g., omega-3 delivery, flavor modulation)

Takeaway for R&D teams:

- Smart formulation = Right technology + Right nutrition goal
- Use this map to prioritize process investments that align with your product’s nutrition claims

How to read the visuals:

- Each sunburst shows technology impact per nutrition goal.
- Bigger segments = stronger contribution

Why it matters: Nutritional performance is no longer just about the base ingredient—how you process it defines digestibility, bioavailability, and long-term health value.

Protein Quality Improvements Are Most Evident in Fermentation and Extrusion29

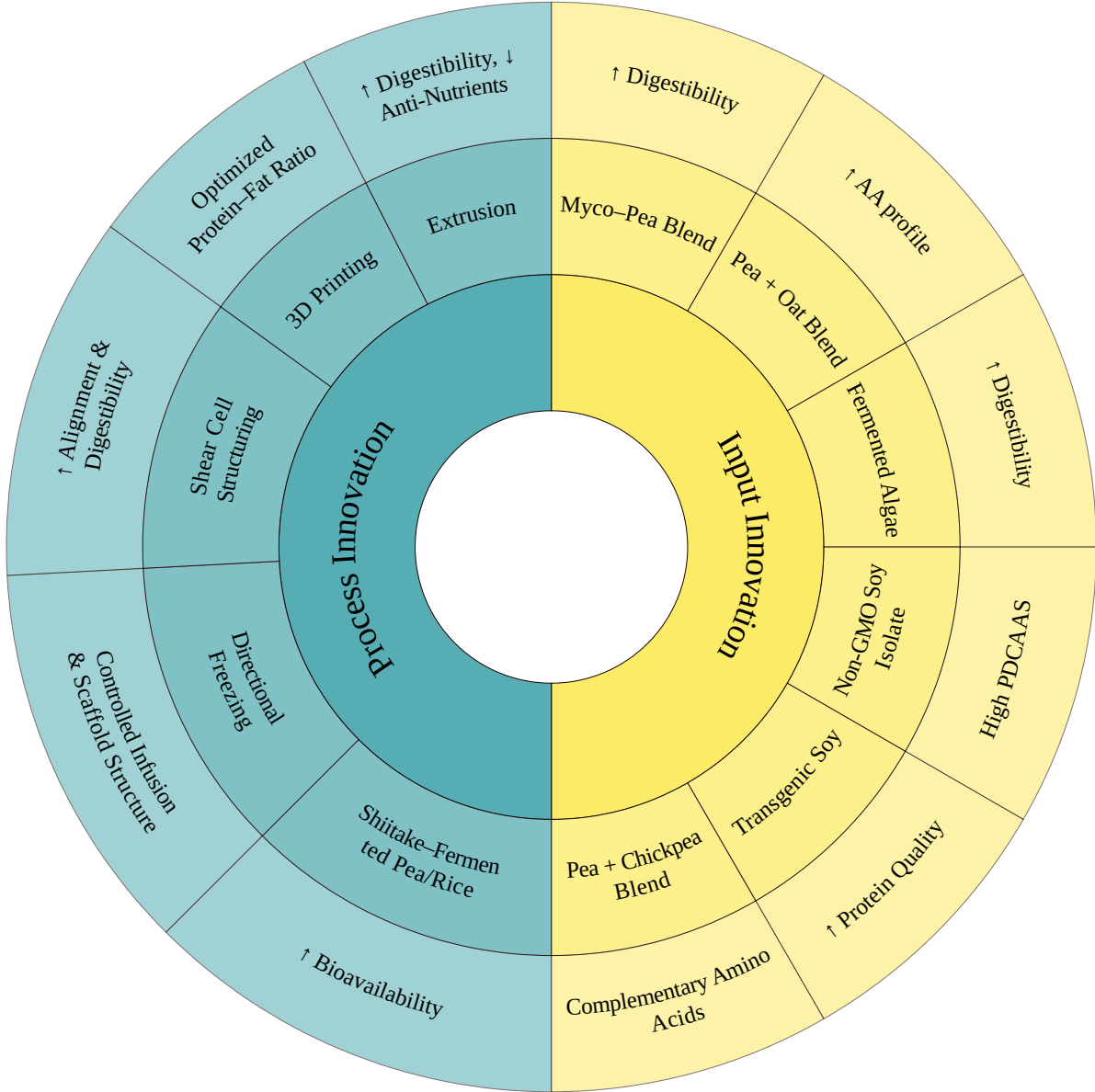
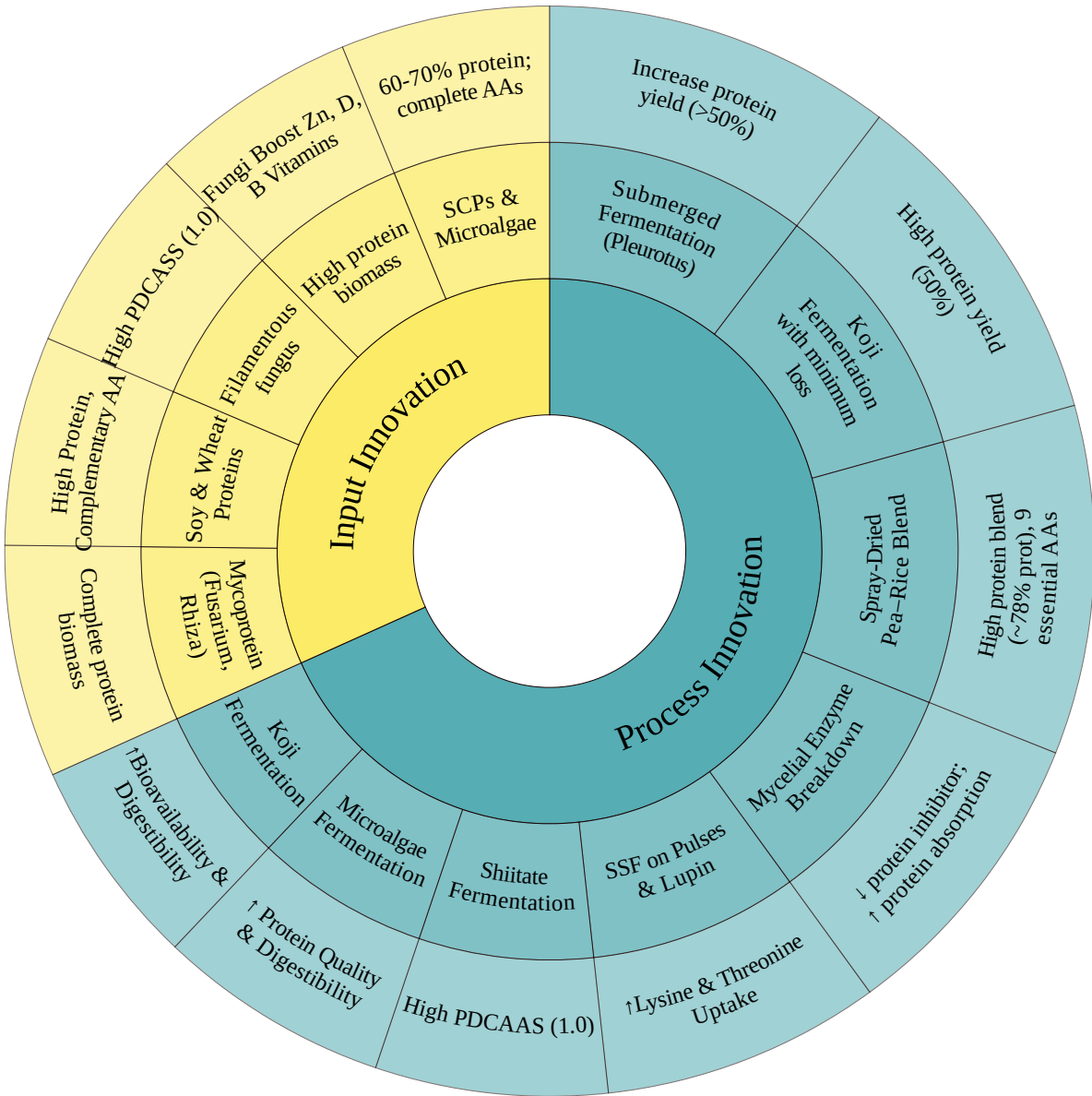
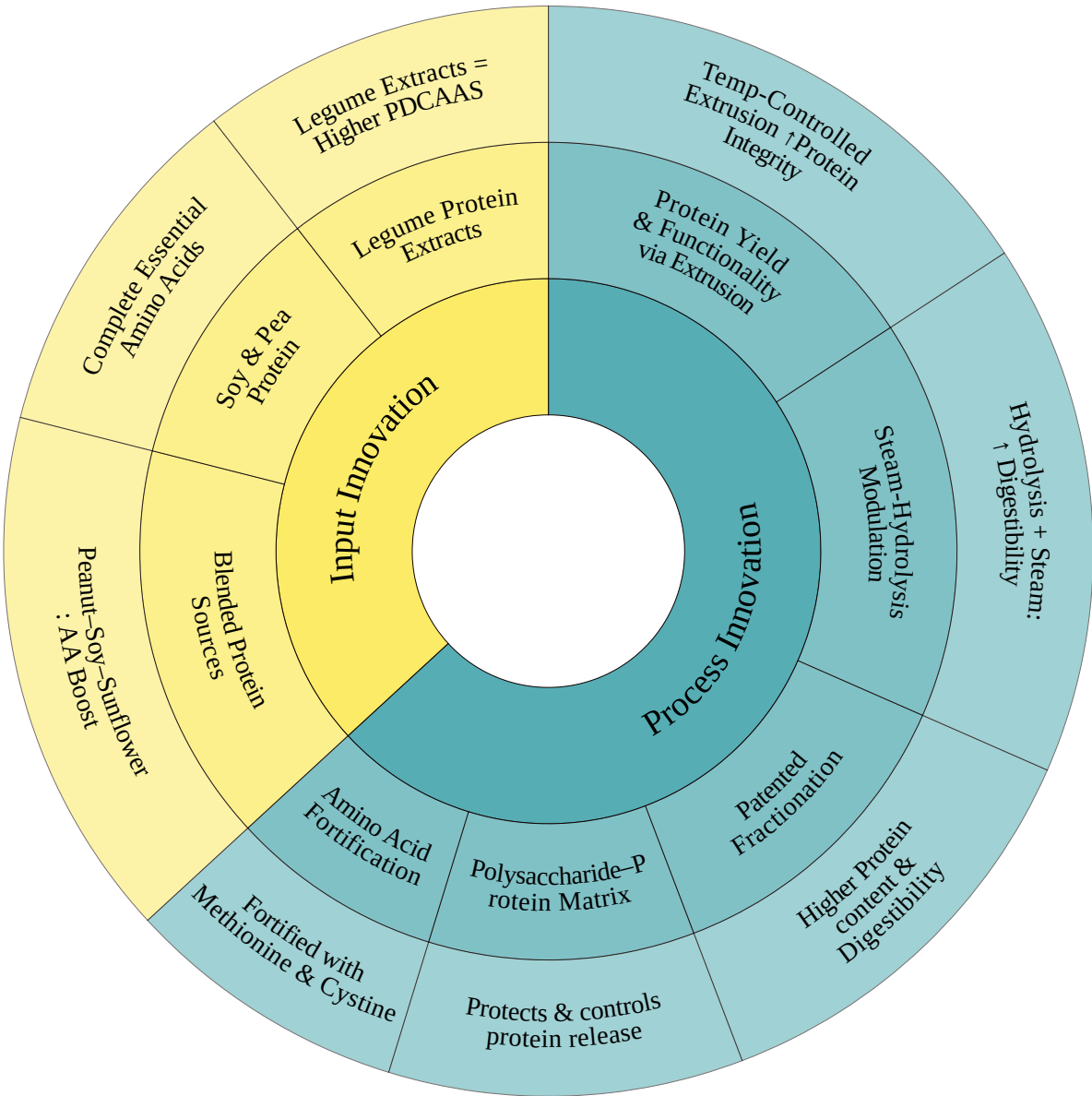
This page maps how fermentation, extrusion, and other technologies improve protein quality in plant-based meat—via input and process innovations. Sunburst size reflects impact strength, helping highlight the most effective interventions.

- Process Innovation
- Input Innovation

Improved Protein quality using Extrusion

Improved Protein quality using Fermentation

Improved Protein quality using Other technologies



Extrusion improves protein functionality by aligning fibers, breaking down inhibitors, and modulating structural properties under shear and heat.

Fermentation technologies enhance protein digestibility and amino acid profile through microbial enzymes, co-culture systems, and strain-level optimization.

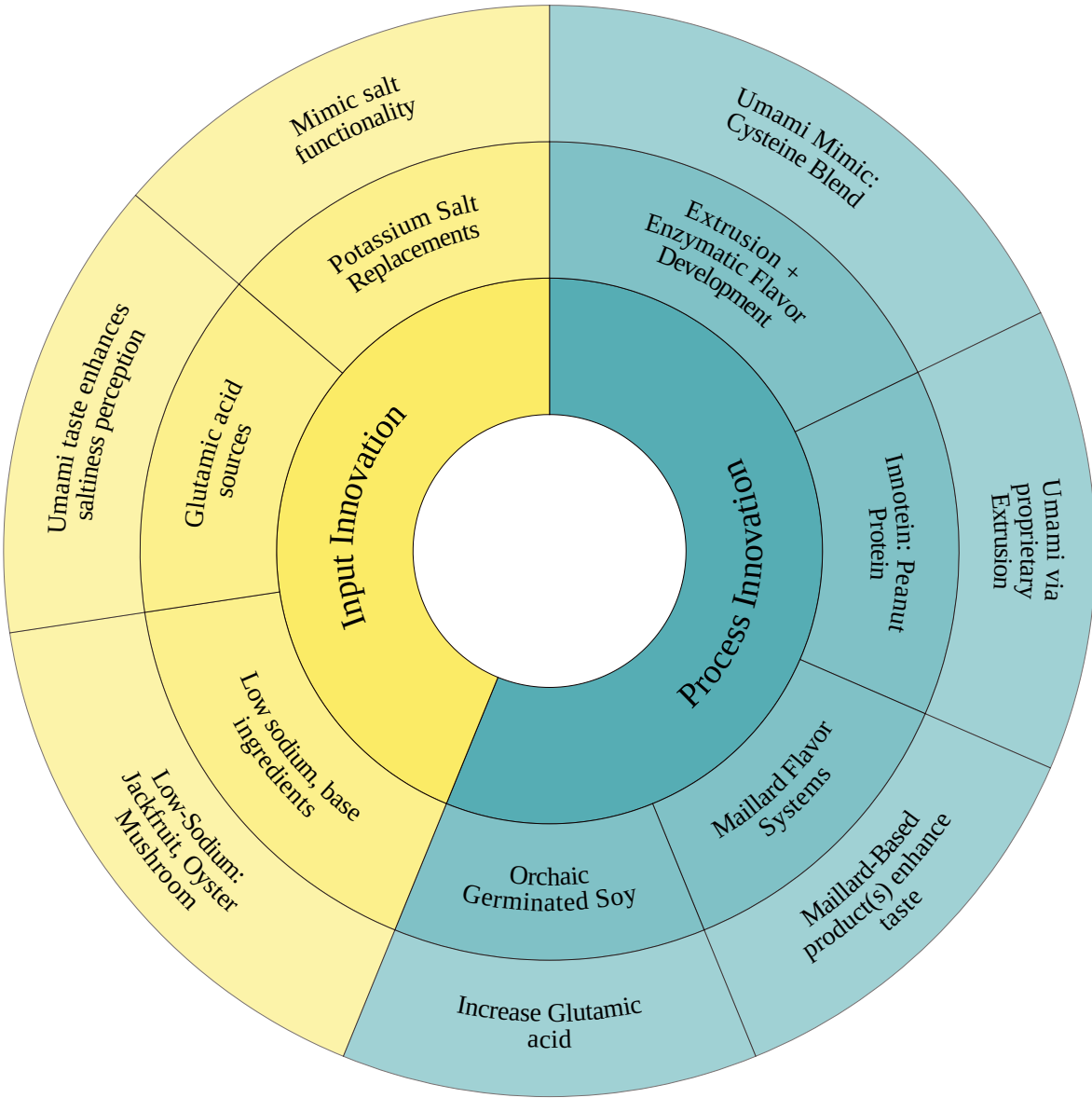
A mix of physical processing and precision inputs—like shear cell tech and amino acid tuning—supports targeted improvements in protein quality and digestibility.

Sodium Reduction in Alternative Proteins: Opportunities Across Processing Platforms 30

This page maps how fermentation, extrusion, and other technologies contribute to sodium reduction in plant-based meat—via input and process innovations. Sunburst size reflects impact strength, helping spotlight the most scalable strategies.

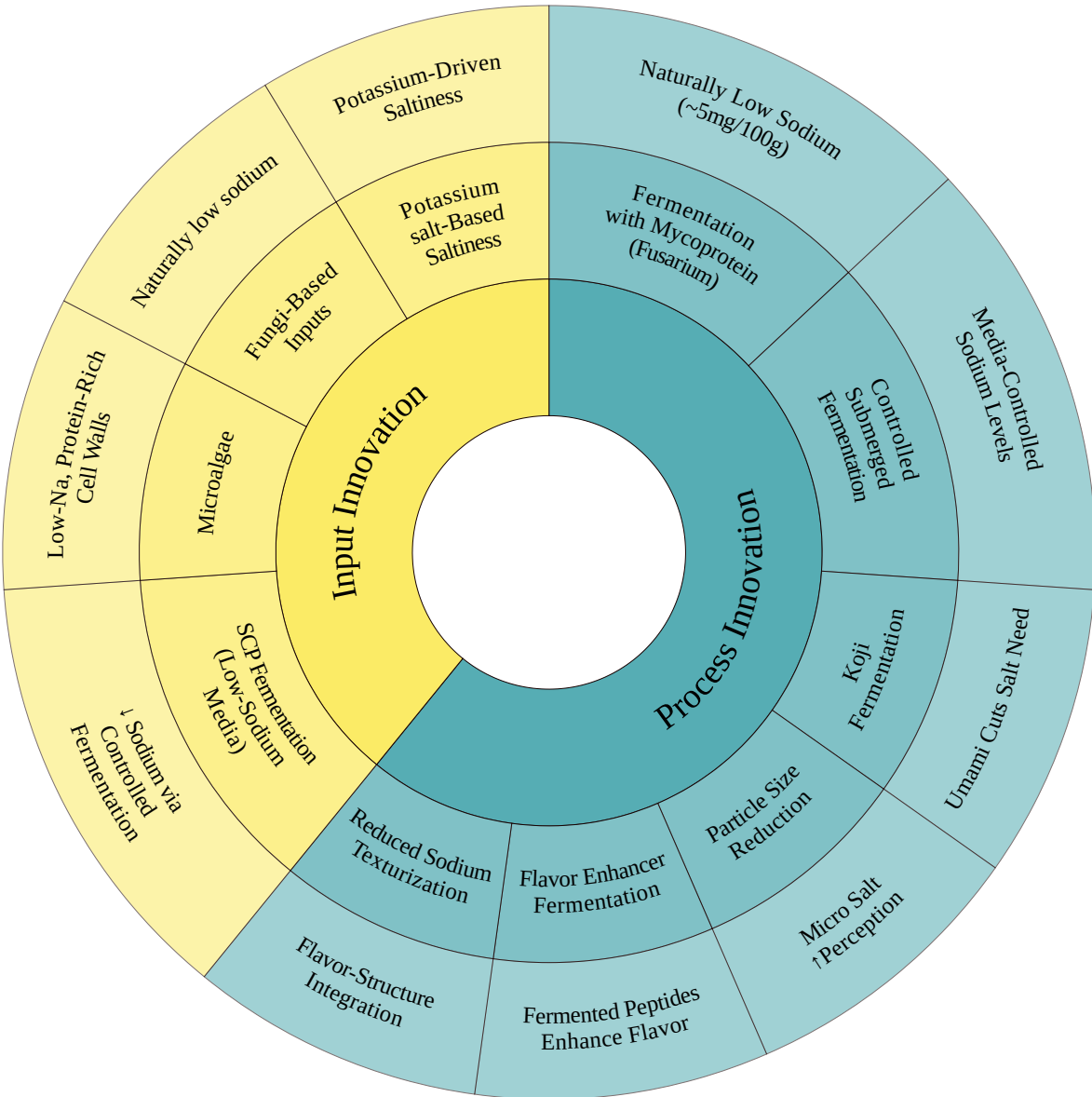
- Process Innovation
- Input Innovation

Sodium Reduction Potential using Extrusion



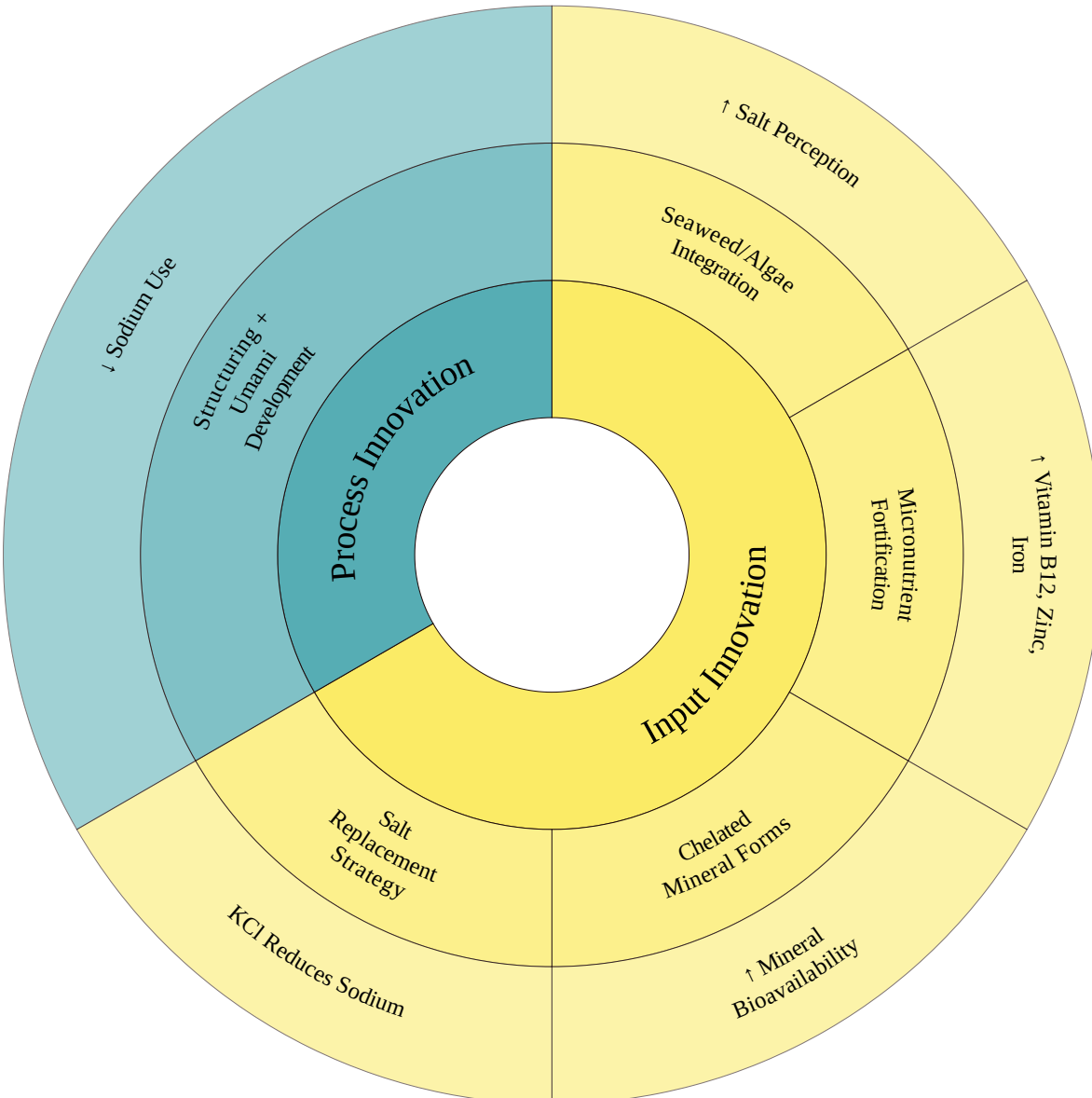
Extrusion contributes indirectly by enhancing salt dispersion, structural retention, and optimizing texture with lower sodium loads

Sodium Reduction Potential using Fermentation



Fermentation enables sodium reduction through umami-enhancing strains, co-fermentation strategies, and intracellular sodium modulation

Sodium Reduction Potential using Other technologies



A mix of salt replacers, mycoproteins, and flavor modulators support sodium reduction by improving perception and reducing the need for added salt

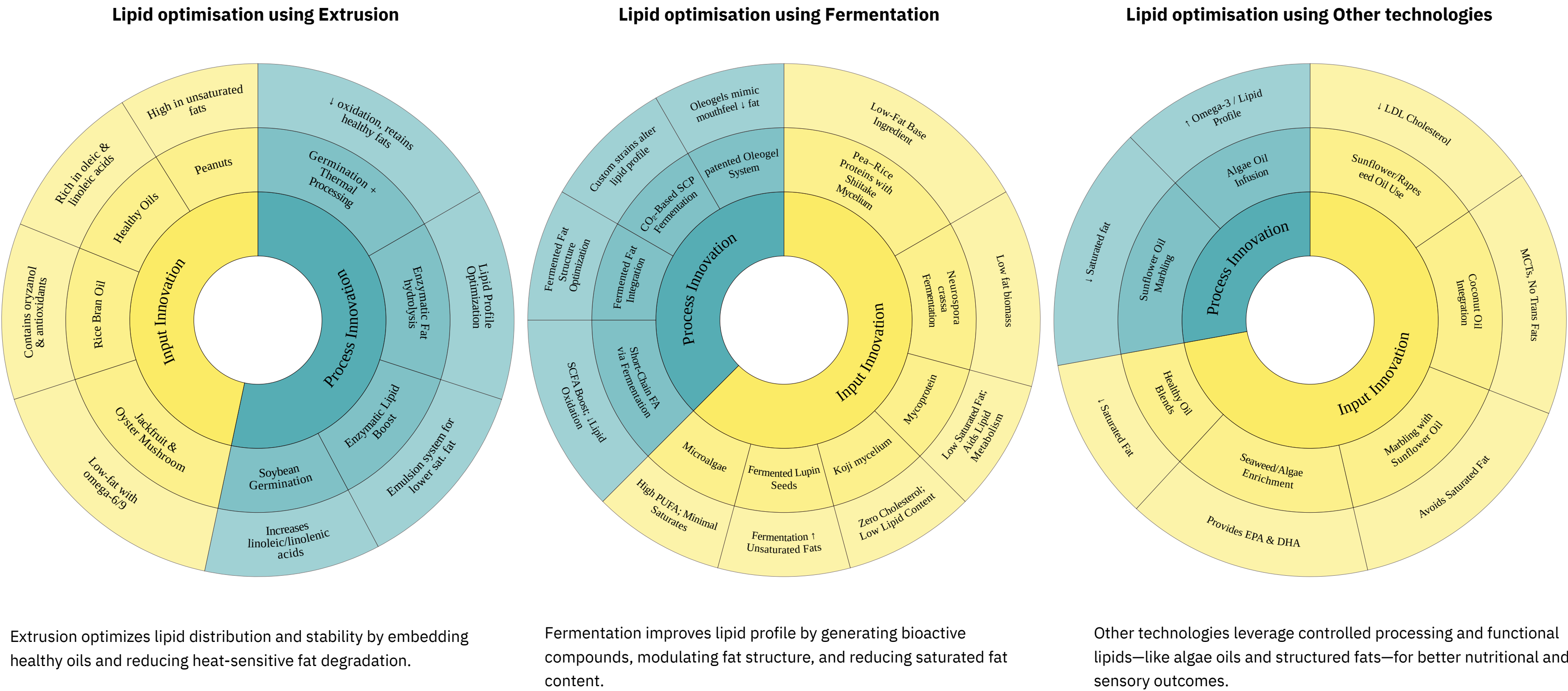
Emerging Lipid Optimization Strategies Focus on Fat Structuring and Fermentation

31

This page maps how fermentation, extrusion, and other technologies support lipid optimization in plant-based meat—through targeted input and process innovations. Segment size reflects impact strength across mechanisms.

Process Innovation

Input Innovation

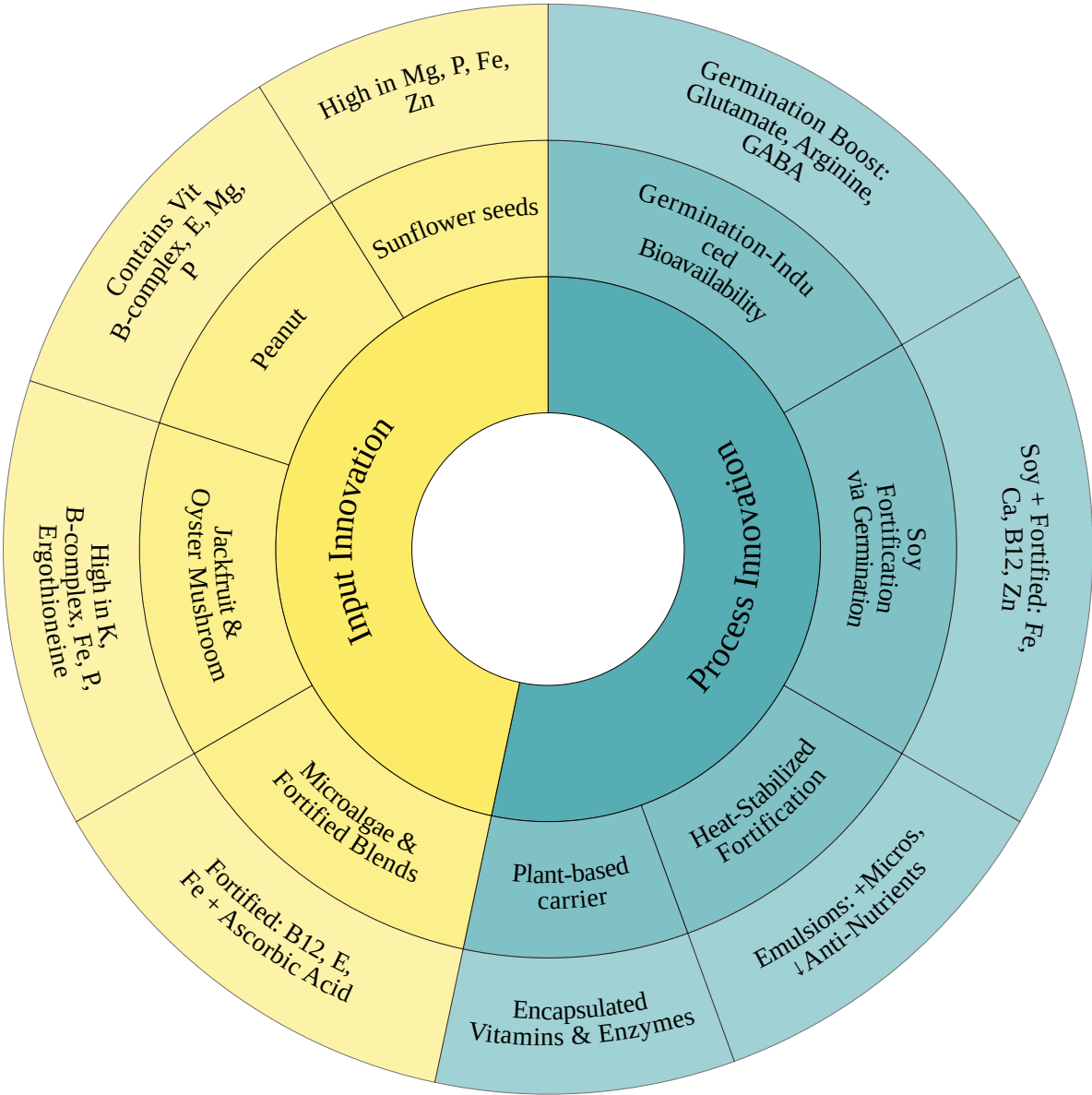


Fermentation and Fortification Support Micronutrient Bioavailability

This page maps how fermentation, extrusion, and other technologies enhance micronutrient content and bioavailability in plant-based meat—through both input and process innovations. Segment size reflects impact strength across mechanisms.

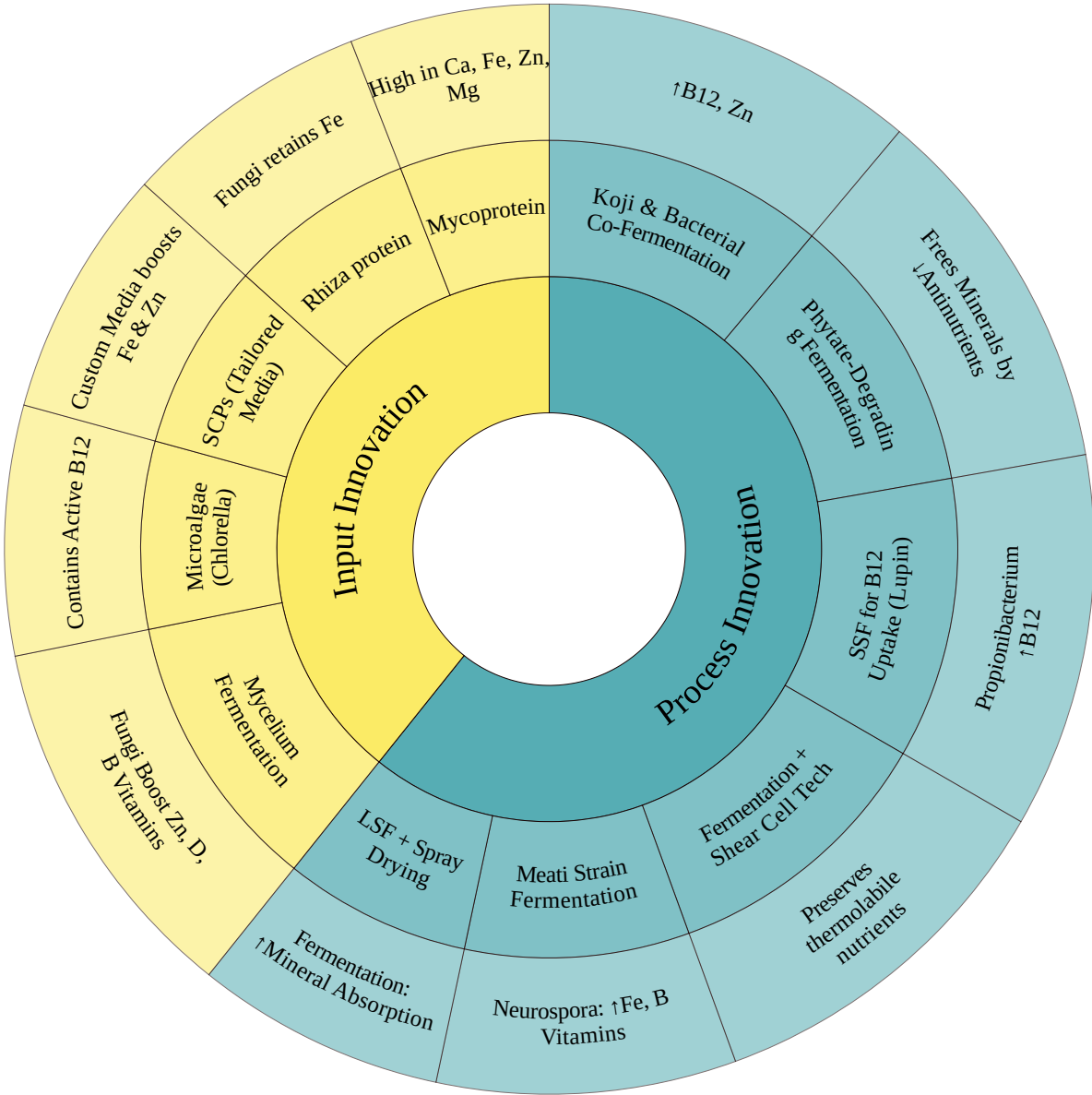
- Process Innovation
- Input Innovation

Micronutrient enhancement using Extrusion



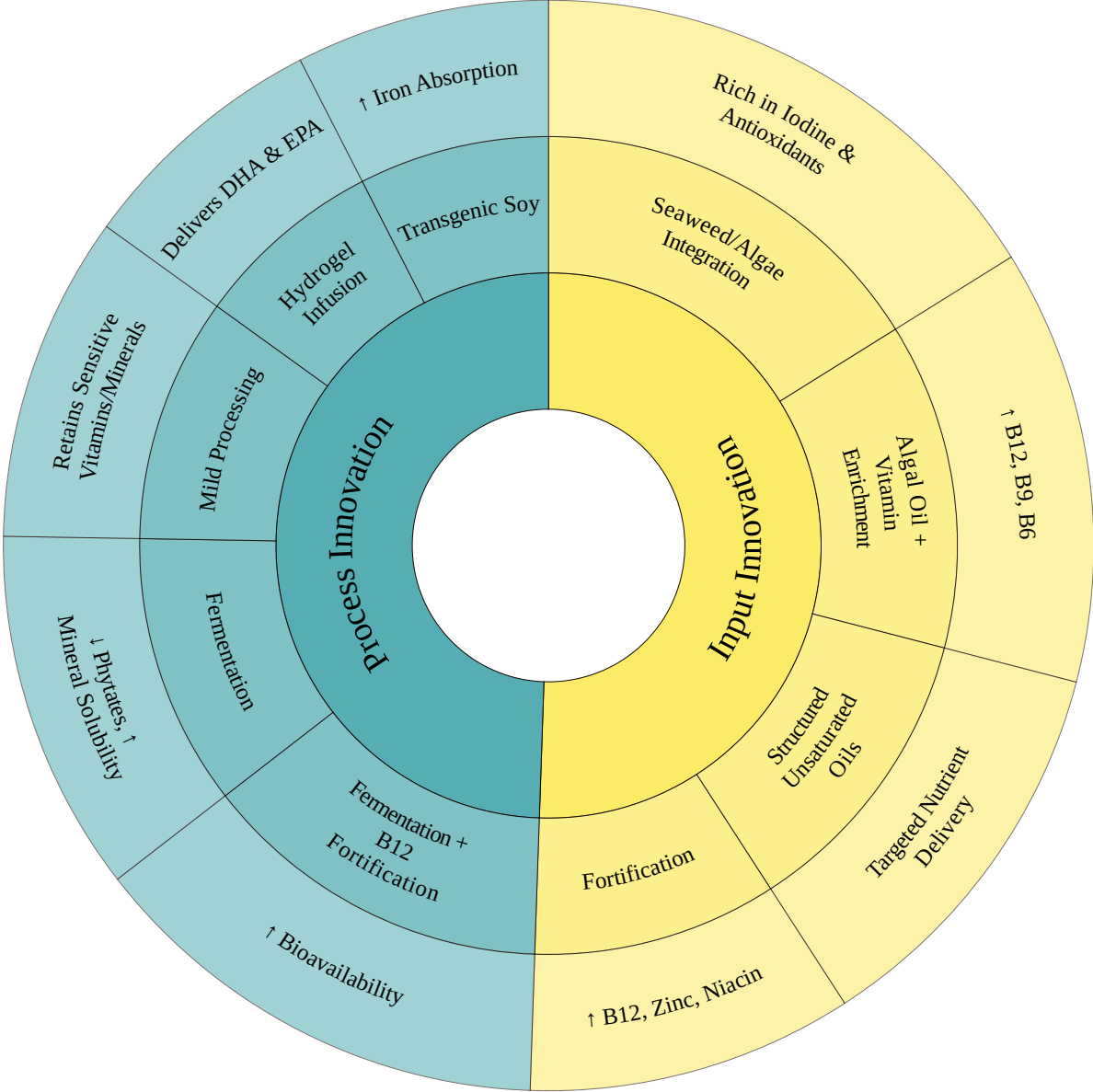
Extrusion supports micronutrient retention and release by minimizing heat loss, reducing anti-nutrients, and enabling stable compound embedding.

Micronutrient enhancement using Fermentation



Fermentation enhances bioavailability and fortification through microbial synthesis, cell wall breakdown, and strain-specific nutrient expression.

Micronutrient enhancement using Other technologies



Gentle processing and precision inputs—like seaweed blends and vitamin stabilizers—support tailored micronutrient delivery and absorption.

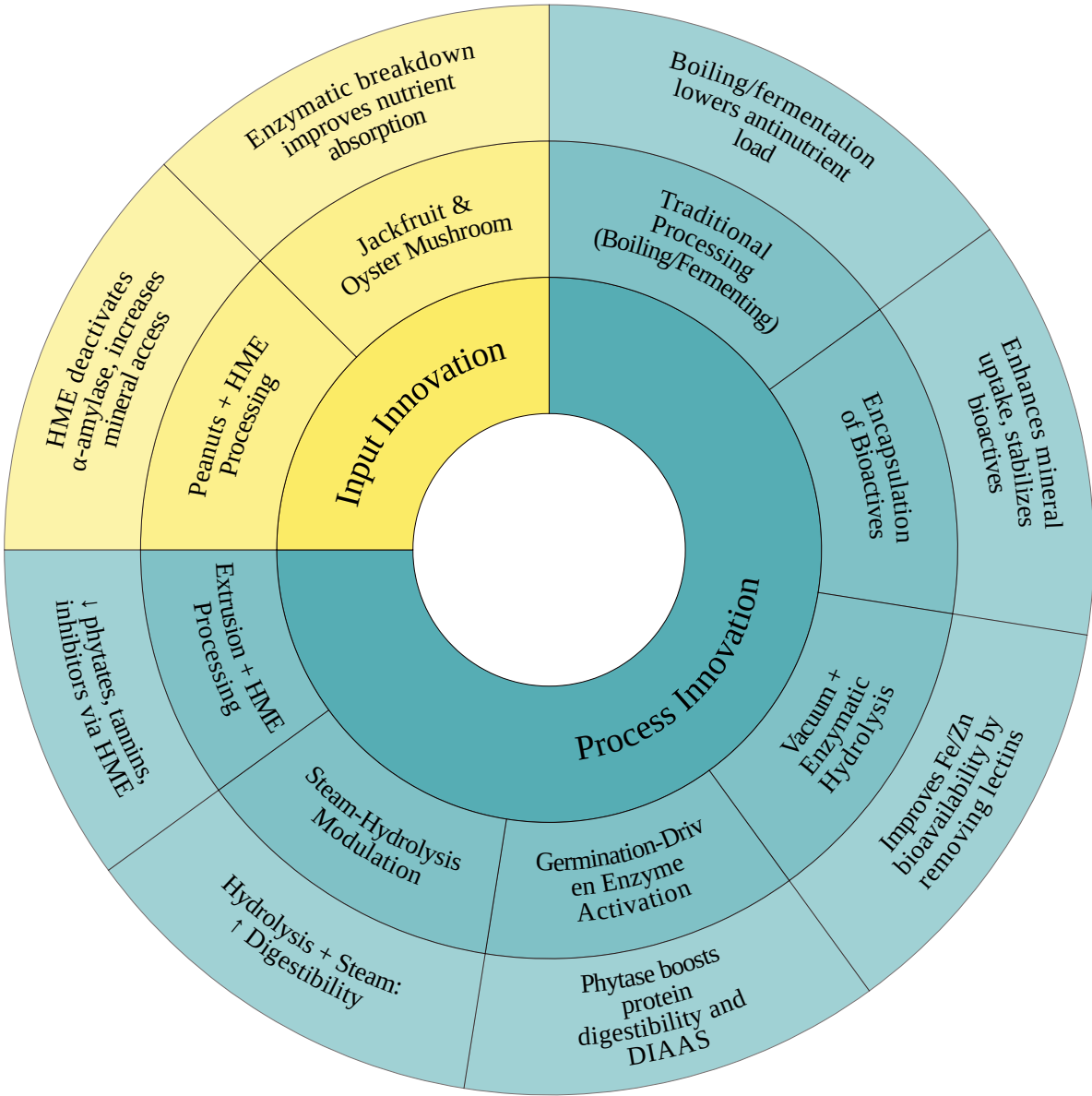
Antinutrient Reduction Is Most Effectively Enabled by Fermentation and Thermal Processing

33

This page maps how fermentation, extrusion, and other technologies reduce antinutrients in plant-based meat—through targeted input and process innovations. Segment size reflects impact strength across mechanisms such as phytate breakdown, protease inhibitor removal, and digestibility enhancement.

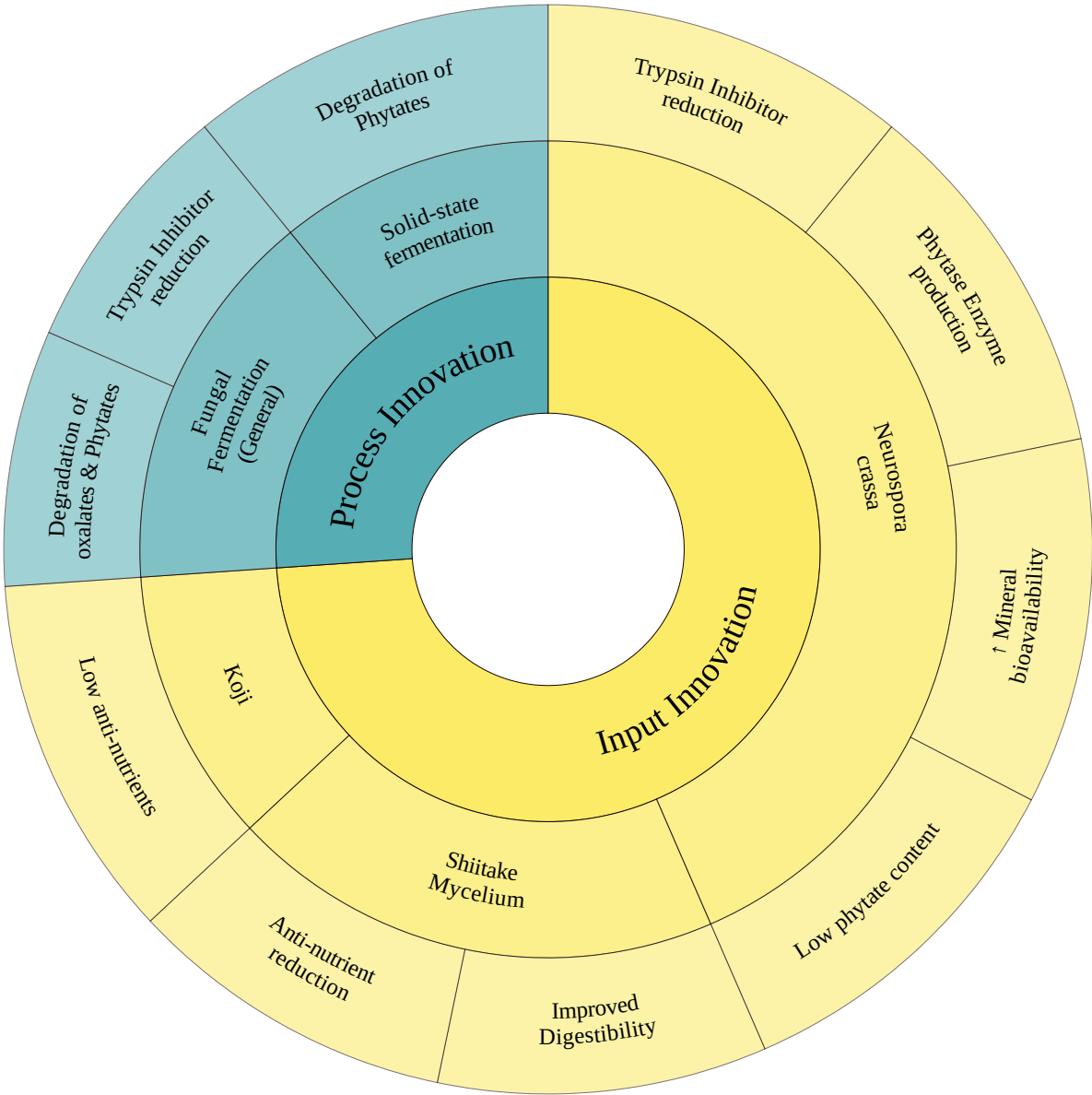
- Process Innovation
- Input Innovation

Antinutrient reduction using Extrusion



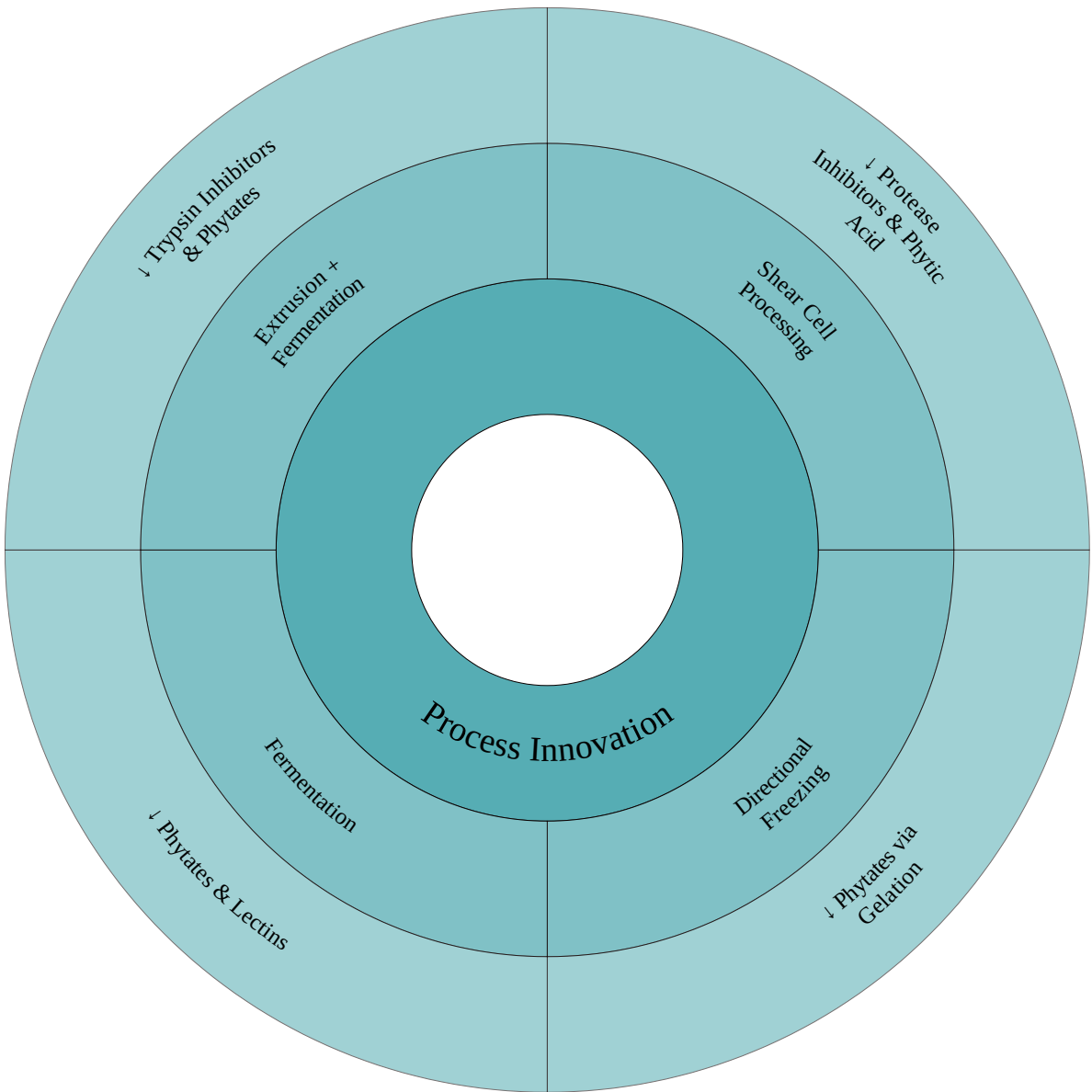
Extrusion breaks down antinutrients via shear, heat, and matrix realignment—enhancing protein bioavailability and mineral absorption.

Antinutrient reduction using Fermentation



Fermentation reduces phytates and trypsin inhibitors through microbial acidification, enzymatic breakdown, and substrate co-fermentation.

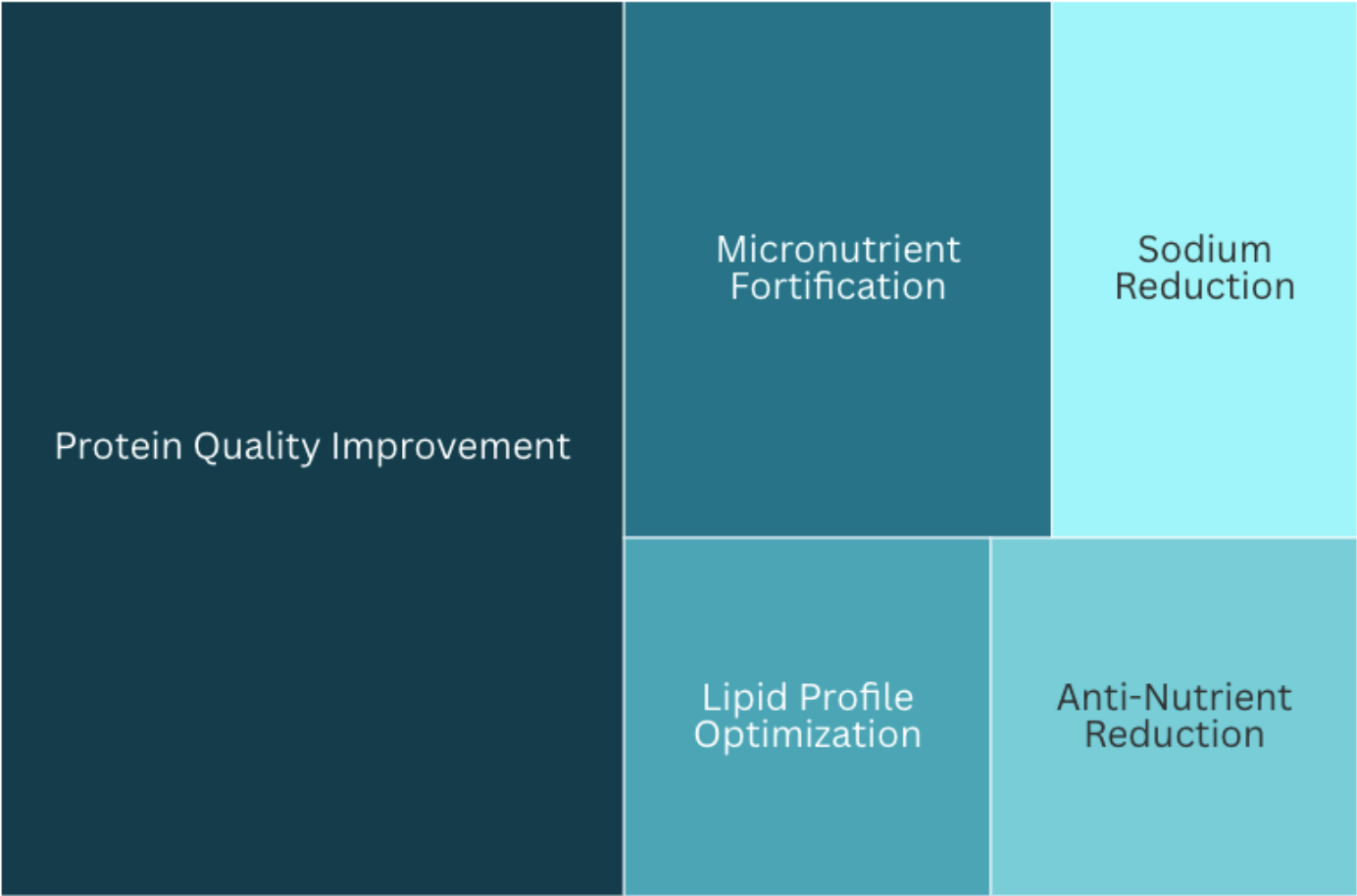
Antinutrient reduction using Other technologies



Other technologies use mechanical and thermal precision to target inhibitors like phytates and lectins—improving nutrient uptake without additives.

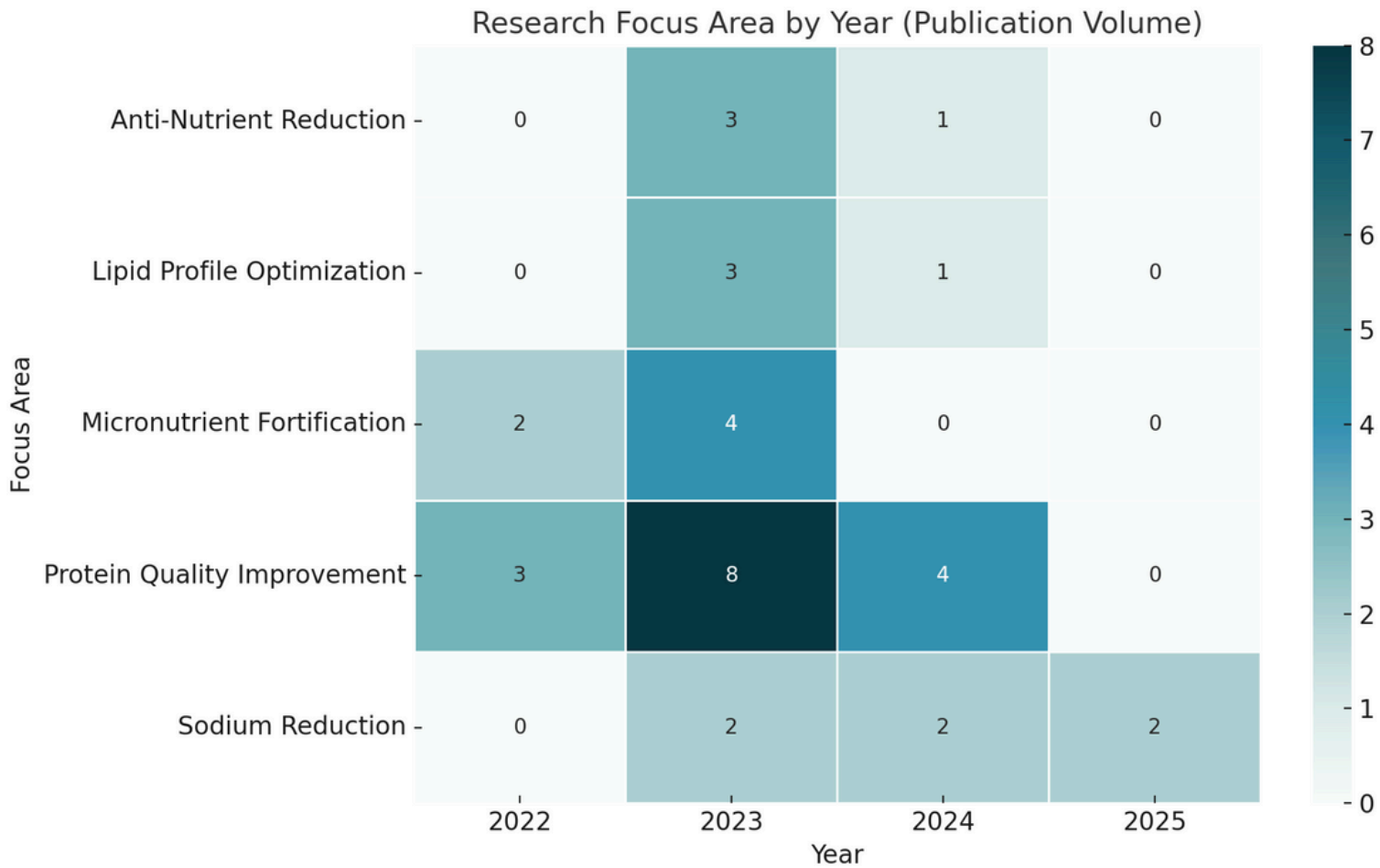
Academic Insights Spotlight Protein Quality and Emerging Nutritional Priorities

To understand how academic research is advancing nutrition in meat alternatives, we analyzed 35 peer-reviewed papers published between 2022 and 2025. These spanned five core focus areas: Protein Quality Improvement (15), Micronutrient Fortification (6), Sodium Reduction (6), Lipid Optimization (4), and Anti-Nutrient Reduction (4). 2023 stood out as the most prolific year, contributing over half of the total publications. This academic snapshot reflects emerging scientific priorities and lays the groundwork for understanding how research is informing industry innovation and IP development.



Protein Quality Leads Research Focus

Protein quality improvement dominates academic efforts, surpassing focus on micronutrients, lipids, and sodium.

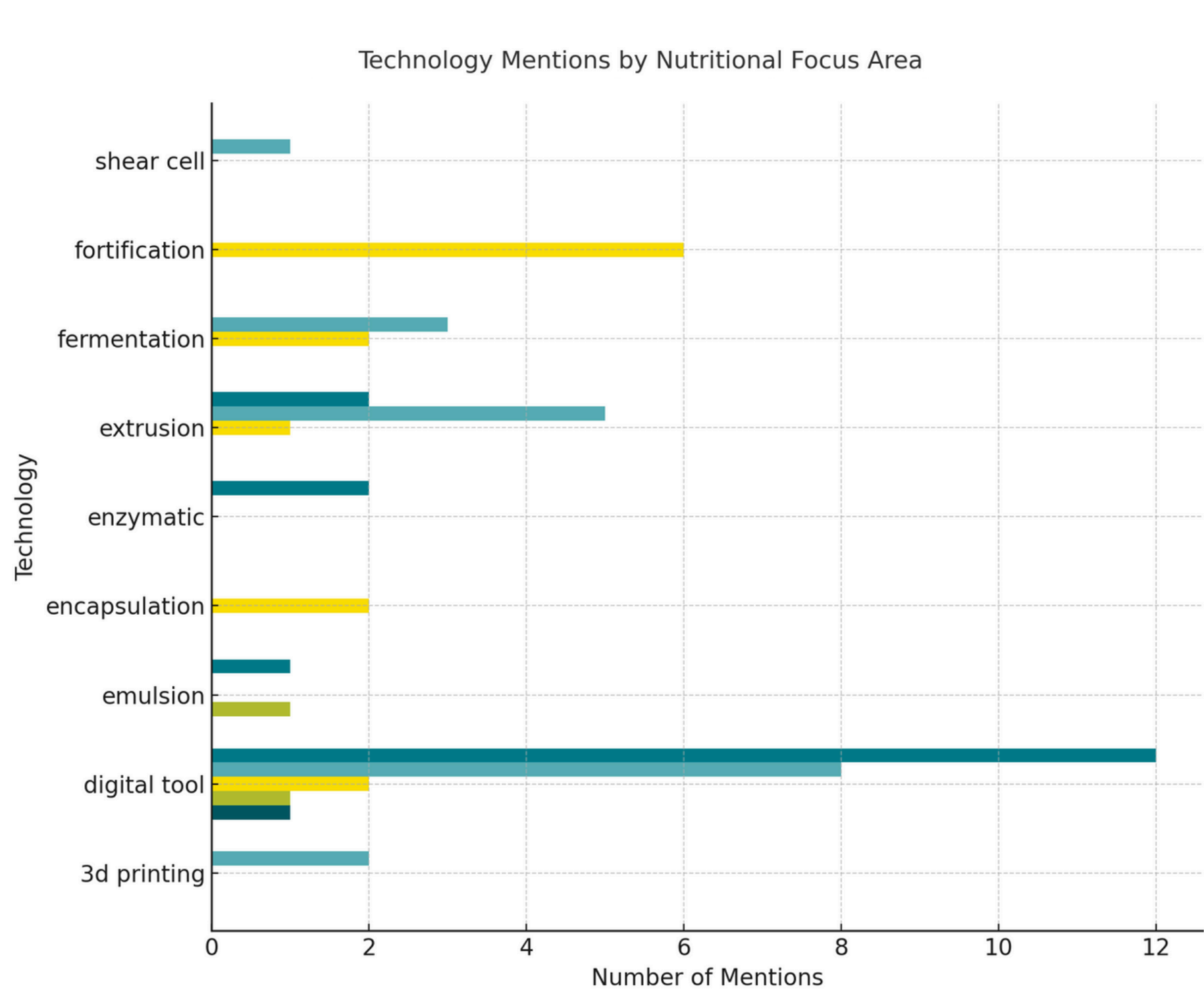


2023: Peak Year for Nutrition Research

Research activity surged in 2023, led by studies on protein quality and micronutrient fortification. Interest in sodium reduction remained steady, while anti-nutrient focus declined post-2023.

Research Highlights Both Cross-Cutting and Specialized Nutrition Technologies

This chart highlights how different processing and formulation technologies contribute to addressing key nutritional challenges in meat alternatives. The visualization brings out several critical insights:



Roles of Enabling Technologies

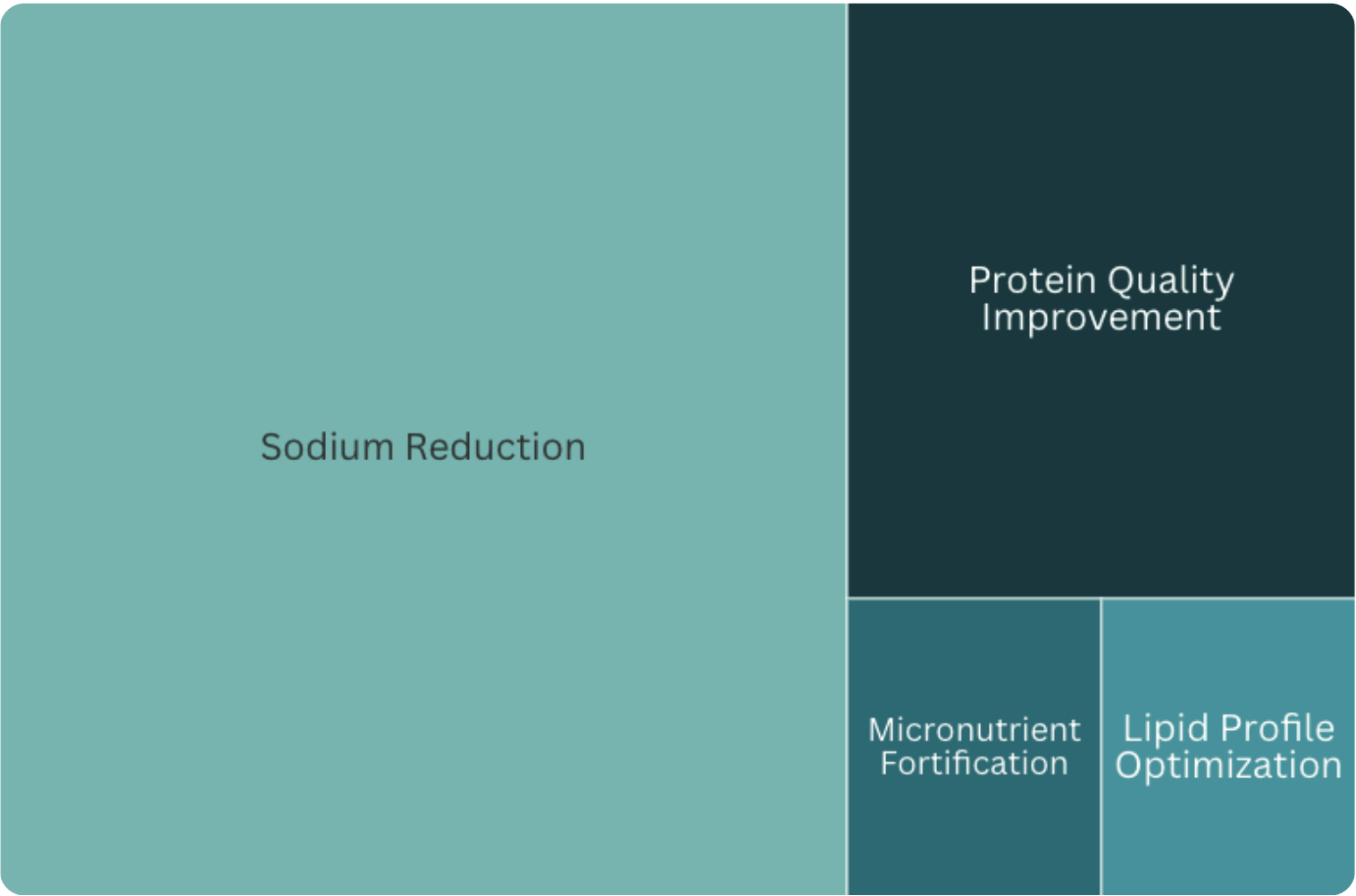
- **Digital tools** (AI-driven platforms and simulation models used to optimize nutrient profiles, ingredient functionality, and formulation strategies in plant-based meat.) span multiple goals — from sodium reduction to protein and micronutrient optimization — signaling growing reliance on computational design.
- **3D printing** enables protein structuring and nutrient layering, with emerging potential for improving amino acid profiles.
- **Encapsulation** is tightly focused on stabilizing micronutrients like iron and B12 through spray-drying and microencapsulation.
- **Emulsion technologies** support healthier lipid systems by reducing saturated fat while maintaining texture.
- **Enzymatic methods** enhance umami and enable sodium reduction without added salt.

These patterns help:

- Identify broadly applicable tools (e.g., AI, enzymes)
- Highlight specialized enablers (e.g., emulsions for fats, encapsulation for vitamins)
- Reveal underutilized opportunities for further research and innovation

Patents Concentrate on Protein and Sodium—With White Space in Micronutrients and ANFs

As the meat alternatives sector evolves, patents offer a window into where companies are placing long-term innovation bets. This section analyzes 26 patents across sodium reduction, protein enhancement, lipid optimization, and micronutrient delivery—while also spotlighting overlooked areas like anti-nutrient reduction and bioavailability. Together, these insights outline a strategic roadmap for future breakthroughs and cross-sector collaboration.



This treemap illustrates patent activity across nutrition focus areas in plant-based meat. Sodium reduction leads, reflecting strong industry efforts toward healthier formulations. Protein quality ranks next, supported by diversified sources and fermentation. In contrast, micronutrient fortification and lipid optimization remain underexplored—signaling clear opportunities for future innovation.



This heatmap shows how top companies are addressing key nutritional challenges in plant-based meat through patent activity. Leaders like Roquette, FermentationExperts A/S, and Chunk Foods emphasize protein quality, while firms such as Trophic and Better Meat Co. target multiple areas. Notably, lipid optimization remains a white space—pointing to clear opportunities for strategic R&D and collaboration.

Technology Scans Reveal Functional Strategies Behind Nutrition Enhancement

Fermentation and extrusion remain leading platforms due to their versatility in improving both protein and lipid outcomes. Meanwhile, tools like predictive modeling, encapsulation, and enzymatic treatments are gaining ground—especially for advancing precision nutrition and nutrient bioavailability.

This shift from traditional structuring techniques to multifunctional, nutrition-forward platforms signals a broader industry evolution. Mapping these overlaps can help guide innovation strategies and uncover opportunities for cross-sector collaboration.

Technology-to-Nutrition Impact Summary

This consolidated table merges two levels of insights:

- Quantitative Mapping – Highlights how frequently each technology appears in relation to specific nutrition goals across academic research and patent data.
- Qualitative Examples – Showcases real-world applications and mechanisms, drawn from peer-reviewed studies, illustrating how these technologies deliver nutritional benefits

Technology	Nutritional Outcomes (Based on Mentions)	Example Application*	Journal-Based Insight (How It Impacts)
Fermentation	Lipid profile, Anti-nutrient	Mycoprotein for cholesterol-friendly products	(No direct mention in journal titles, but implied through related protein/lipid reduction studies)
Extrusion	Protein quality, Sodium reduction	HME/TVP for fibrous meat analogues	Improves protein texture and nutrient retention through high-moisture processing
Digital Tools	Protein, Sodium, Micronutrient	AI for formulation & predictive nutrition	Supports ingredient screening and flavor optimization to reduce sodium and enhance protein targeting
Encapsulation	Micronutrient fortification	Spray-dried iron/B12 systems	Stabilizes micronutrients using encapsulation and spray-drying techniques
Emulsion Techniques	Lipid optimization, Sodium reduction	Oil-in-water blends for mouthfeel	Enables structured lipid systems for healthier fat replacement with improved palatability
Enzymatic Processing	Sodium reduction, Micronutrient bioavailability	Enzyme-treated isolates	Enhances saltiness perception and nutrient absorption through enzymatic pre-treatment

Based on research journal and patent analysis; wording simplified for clarity. Fermentation is referenced conceptually but not often explicitly named in journals.

Sodium Innovation Dominates Patent Activity; ANF Reduction Remains Untapped38

An analysis of 26 patents shows where companies are placing innovation bets in plant-based meat nutrition. Sodium reduction leads with nine filings, followed by protein quality (6) and lipid optimization (4). In contrast, micronutrient fortification (1 patent) and anti-nutrient reduction (0 patents) remain largely overlooked, highlighting clear opportunities for R&D.

- Only two companies—DSM-Firmenich and Fable Holdings Pty Ltd.—have patents spanning multiple nutrition domains, suggesting that most innovation remains siloed. This fragmentation underscores the need for integrated strategies that tackle multiple nutritional challenges in tandem.
- Notably, anti-nutrient reduction is entirely absent from the patent landscape, despite its crucial role in bioavailability. Similarly, fortification and lipid innovations are still emerging, offering open ground for R&D leadership.

Together, these patterns reveal not just where innovation is happening, but where it's urgently needed—guiding future product development, partnerships, and IP strategy in the smart protein space

Nutritional Focus Area	Innovation Density	Key Players	Technology Mode	Example innovation
Sodium Reduction	◆ High	Roquette, Fable Holdings, Yantai Oriental	Ingredient + Process + Flavor	Low-sodium isolates, compound salts, umami-rich mushroom systems
Protein Quality	● Moderate (indirect)	Trophic LLC, Chunk Foods, Better Meat Co.	Source diversification + Fermentation	Mycoprotein biomass, seaweed blends, pulse–oil matrices
Fat Optimization	⚠ Low	Fable Holdings	Textural mimicry	Starch-based fat gels mimicking juiciness and mouthfeel
Micronutrient Fortification	! Very Low	FermentationExperts A/S (indirect only)	Fermentation (enabler)	Indirect bioavailability boost via phytate breakdown
Anti-Nutrient Reduction	⛔ None Detected	-	-	White space—no patent activity observed

Firms that align patent strategy with underexplored nutrition goals—like lipid optimization and micronutrient delivery—are poised to shape the next frontier of competitive advantage.

Focus Areas – Alignment & Gaps

- Protein Quality dominates both, but far more in research (15 vs 4) — showing strong academic work not yet fully commercialized.
- Sodium Reduction is more prominent in patents (9 vs 6), likely driven by regulatory and market needs.
- Micronutrient Fortification and Lipid Optimization are mostly research-led, indicating early exploration.
- Anti-nutrient Reduction appears only in research — a clear gap for future IP development.

Shared Themes, Different Objectives

- Research focuses on broad challenges (e.g., amino acid balance, bioavailability).
- Patents prioritize product-ready solutions (e.g., sodium-reduced isolates, structured fats).

Technology Use & Language Disconnect

- Common technologies (e.g., fermentation, encapsulation) are present in both but described differently.
- Harmonizing language could improve translation from lab to market.

Time Trends

- Research output peaked in 2023; patent timelines unclear due to limited metadata.

Standalone Observations

- Research highlights: spray-drying, fermentation, anti-nutrient reduction.
- Patents emphasize: sodium reduction, texture, fat mimetics — focused on product performance.

From Insight to Illustration: Understanding Research–Patent Overlap

Building on the comparative analysis, the Venn diagram offers a visual summary of how research and patents align and diverge in their focus areas.

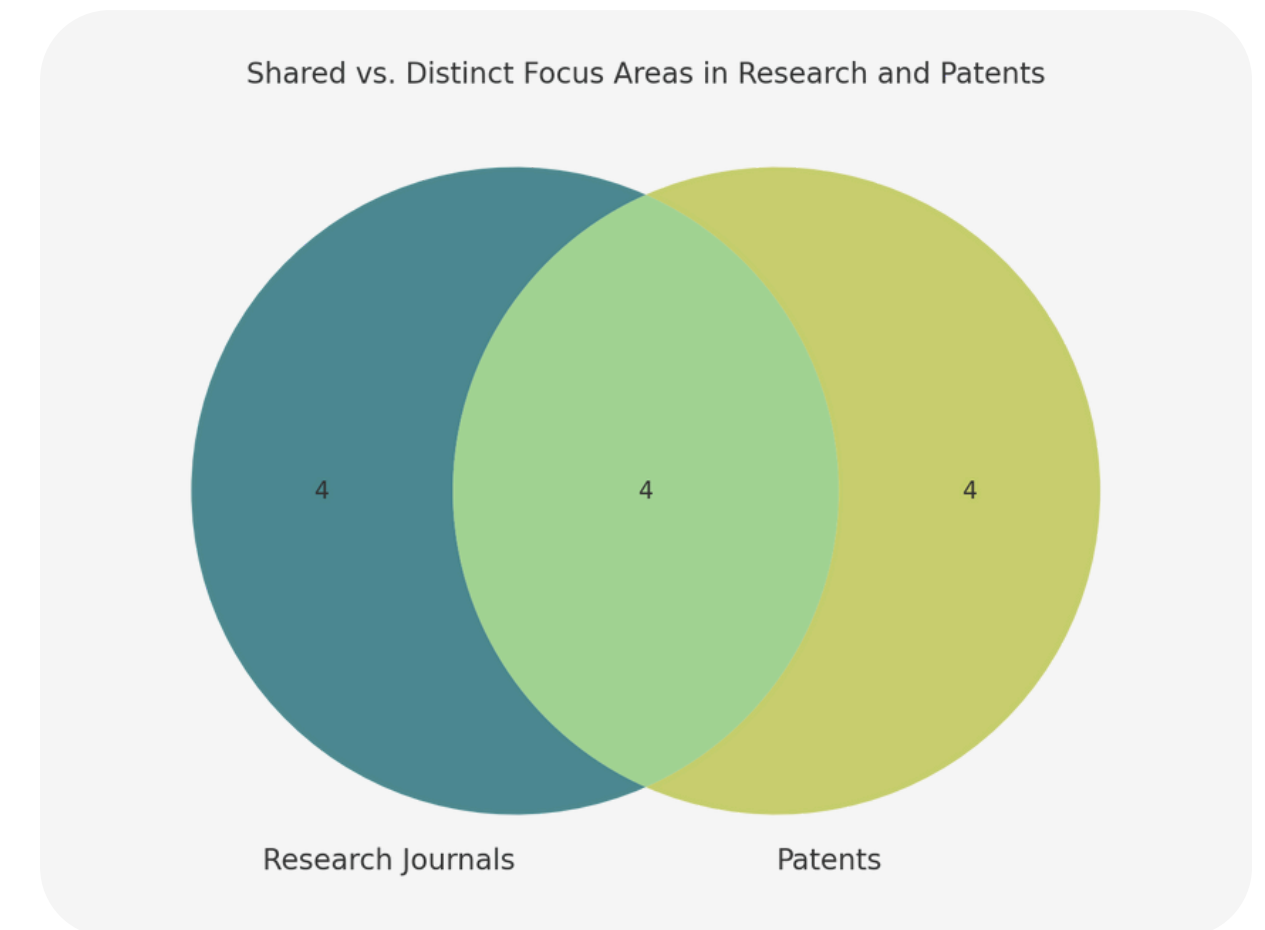
What Do “Shared” and “Distinct” Mean?

- Shared focus areas appear in both research and patents — indicating mutual priorities across academia and industry.
- Distinct focus areas appear in only one — reflecting either early-stage exploration (research) or market-driven development (patents).

What the Diagram Shows:

- **Research-only:** Topics like anti-nutrient reduction, vitamin encapsulation, and bioavailability enhancement remain largely academic — highlighting innovation potential yet to be commercialized.
- **Patent-only:** Solutions such as sodium-reduced isolates, structured fats, and fibrous analogues target market-ready applications — often with limited academic exploration.
- **Shared themes:** Technologies like fermentation, protein quality improvement, and fiber structuring show strong continuity — where science and commercial product development are reinforcing each other.

This mapping sharpens the view on where translation is working, where it’s still fragmented, and where the next wave of smart protein innovation could emerge.



This SWOC (Strengths, Weaknesses, Opportunities, Challenges) framework synthesizes the research–patent mapping and technology analysis presented in the report. It underscores:

- The technical momentum driven by active ingredient/process R&D and early-stage support.
- The gaps in translation, where limited validation and fragmented public data slow commercialization.
- The growing market pull for nutrition-enhanced products, especially in micronutrient fortification.
- And the barriers that must be addressed — from regulatory fragmentation to the public perception of UPFs.

This landscape analysis reinforces the importance of bridging academic insights and commercial readiness — not only to advance product innovation, but to meet evolving consumer and policy demands.



We developed a summary scoring framework, traffic light system, presented at the back of this report, distills each technology’s maturity, innovativeness, and nutritional impact into a traffic light system to guide strategic prioritization.

Top 100 Companies Contributing to Nutrition-Driven Innovation

Solution Providers



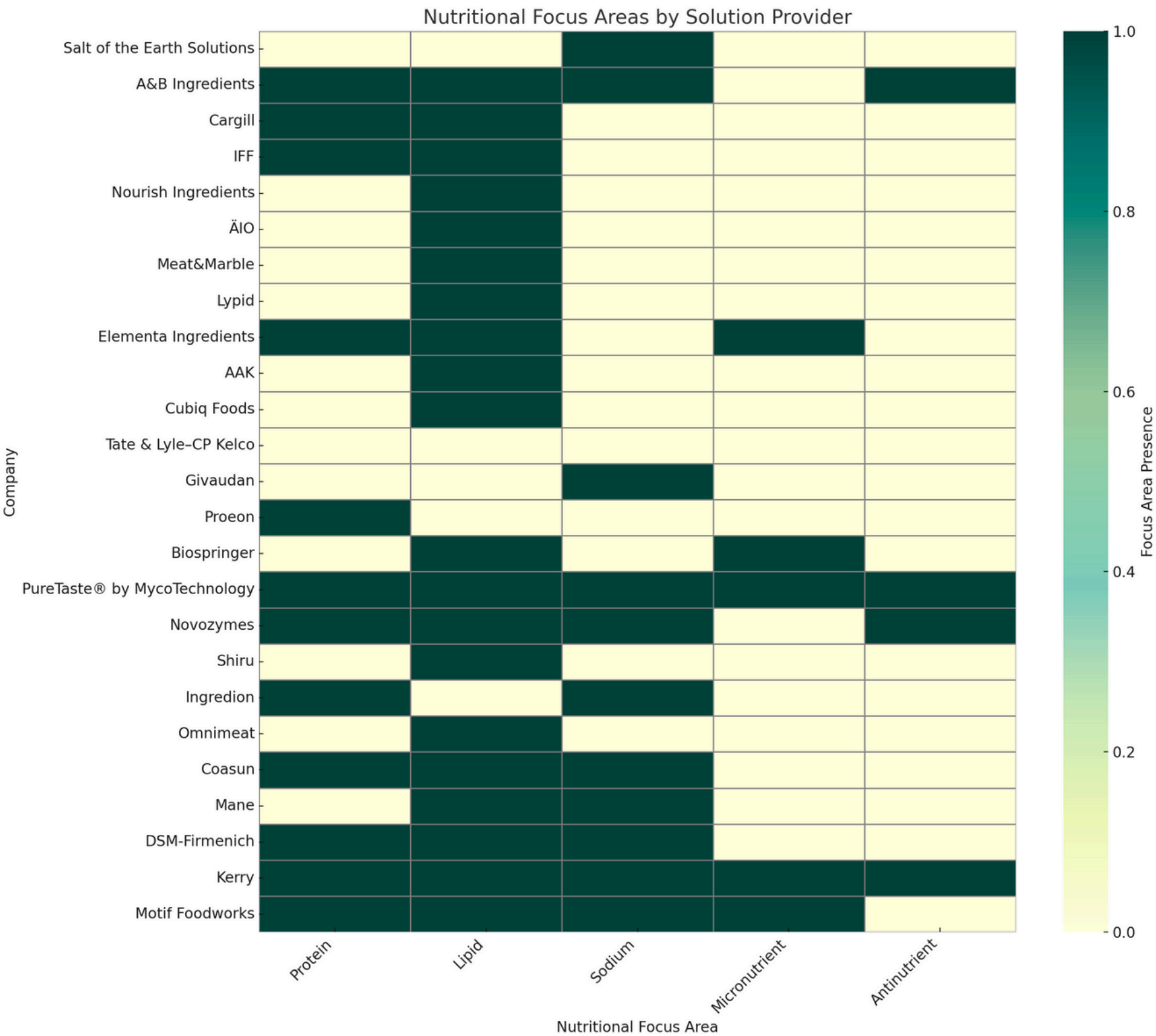
Meat Analogues/Extenders



End Product Company



Solution Providers Are Catalyzing Functional Nutrition Platforms 42



To advance the nutritional profile of plant-based meat, ingredient solution providers are delivering next-generation interventions — from protein and fat optimization to targeted micronutrient systems and anti-nutrient reduction. This slide maps key players whose technologies are directly enabling health-forward reformulation.

Mapping Ingredient Solutions Across Core Nutrition Targets

This heatmap highlights 23 leading providers and their contributions across five nutrition priorities: protein quality, lipid optimization, sodium reduction, micronutrient fortification, and anti-nutrient removal.

Each filled cell reflects an active intervention — whether through a functional ingredient, processing aid, or formulation system. The visual reveals areas of concentrated innovation (e.g., protein and lipids) as well as whitespace ripe for future R&D investment (e.g., anti-nutrient reduction).

Broad Reach Meets Targeted Innovation

Players like Kerry, IFF, and Biospringer offer wide-ranging solutions across multiple nutrition goals. Emerging specialists like Shiru, ÄIO, and Proeon contribute differentiated value in clean-label, fermentation-enabled, or micronutrient-focused strategies. This reflects a dual-track innovation landscape — blending scale with specialization.

⚠️ Note on Company Coverage

Out of 35 solution providers studied, only 25 are shown here. The remaining were excluded due to lack of verified product information from direct contact

Case Studies: Translating Innovation Into Measurable Nutrition Gains

This section spotlights five pioneering companies advancing the nutritional quality of plant-based meat through diverse technologies—from AI-enabled formulation and molecular farming to mycelial structuring and clean-label extrusion.

Together, these case studies illustrate how science-driven innovation is being applied across global markets to tackle key nutritional challenges—improving protein quality, reducing sodium, and enhancing micronutrient delivery.

Shandi Global: Multi-Patent Platform Delivers Clean-Label Nutrition Gains

Shandi Global, a Singapore-based startup, has developed a five-patent, plant-based meat process that elevates nutrition without compromising sensory quality. Their technology stack enhances sodium reduction, protein quality, and micronutrient density—all while maintaining a clean-label formulation.

The process begins with a dry blend of proteins and fibrous components, which is gently hydrated with enzymatic agents to form a uniform mass. This step reduces sodium via enzymatic breakdown. Subsequent thermal treatment deactivates anti-nutritional factors (ANFs) and enhances protein bioavailability.

The hydrated mass is split into two parts:

1st Mass: Combined with amino acids, lipids, and dextrose to generate natural chicken-like flavors via Maillard browning—eliminating the need for artificial flavorings.

2nd Mass: Enriched with micronutrients such as B12 and iron, plus functional binders. The two masses are recombined and extruded to yield a fibrous, meat-like structure with improved texture and consumer appeal. These innovations advance the goal of making plant-based proteins not just viable—but superior—alternatives.

Summary of Nutritional Enhancements Across Shandi’s Multi-Step Process

Process Step	Nutritional Impact
Enzymatic Hydration	Sodium reduction
Thermal Treatment	Anti-nutrient reduction, protein quality improvement
Maillard Reaction (1st Mass)	Natural flavor formation without additives
Micronutrient Fortification (2nd Mass)	Fortification with iron, B12, and other key nutrients
Extrusion	Meat-like texture, enhanced consumer acceptance

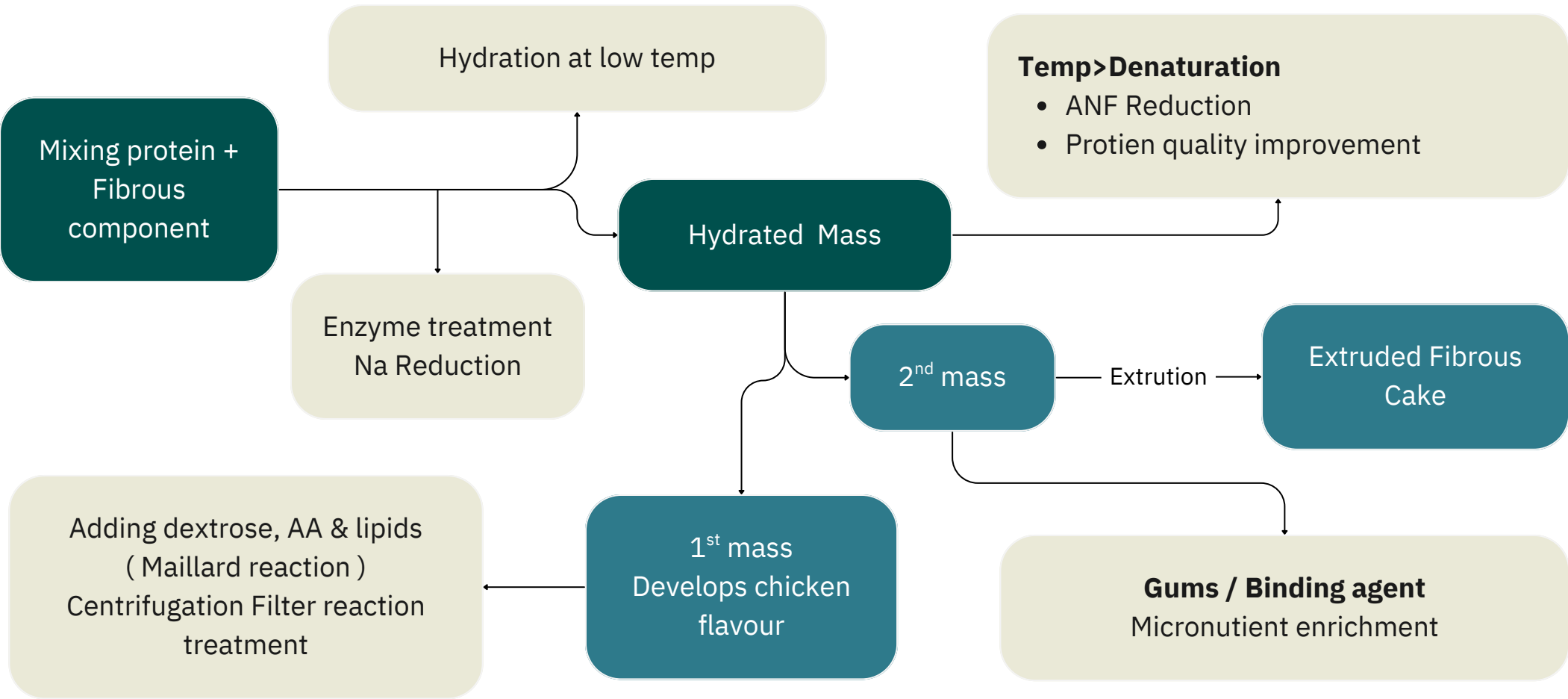
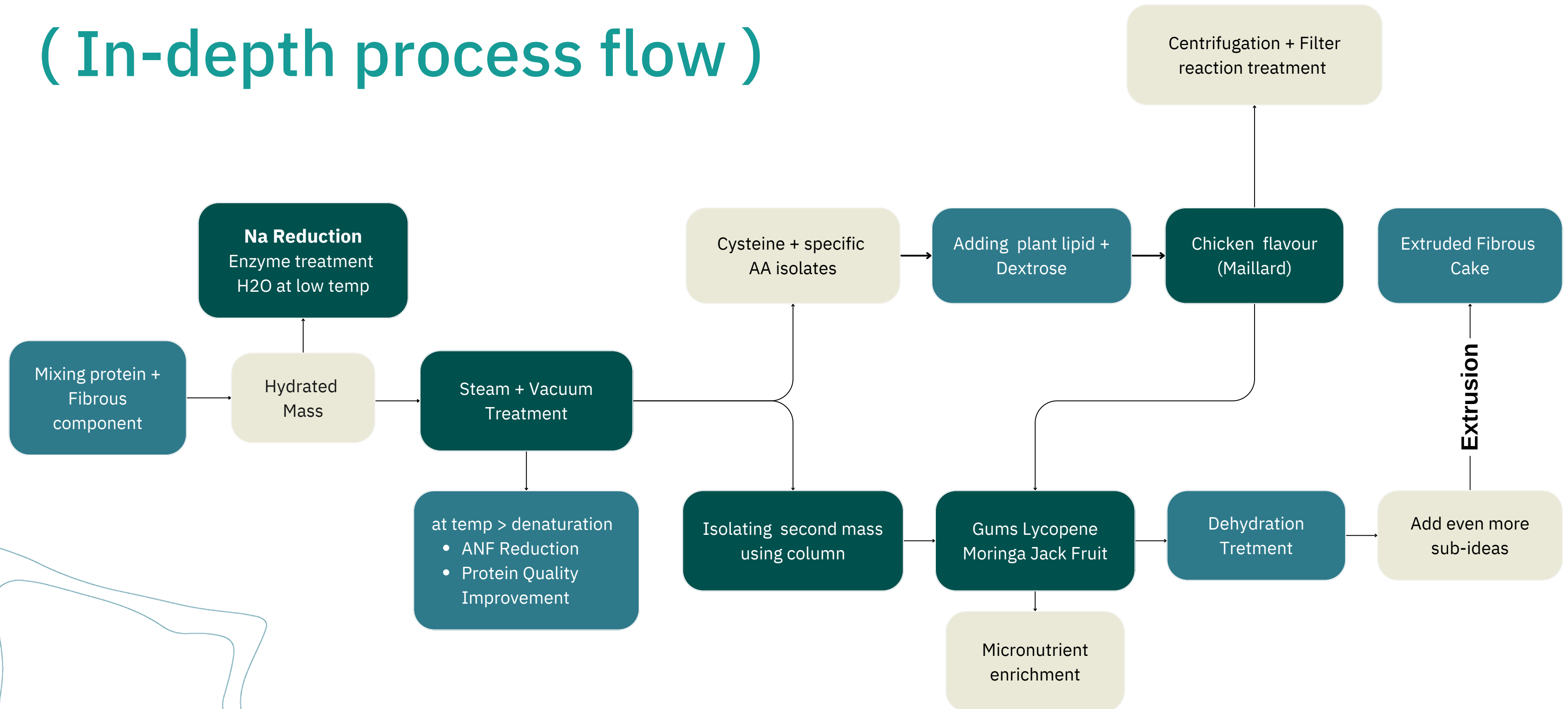


Illustration adapted from Shandi Global’s published process patents

SHANDI GLOBAL

(In-depth process flow)

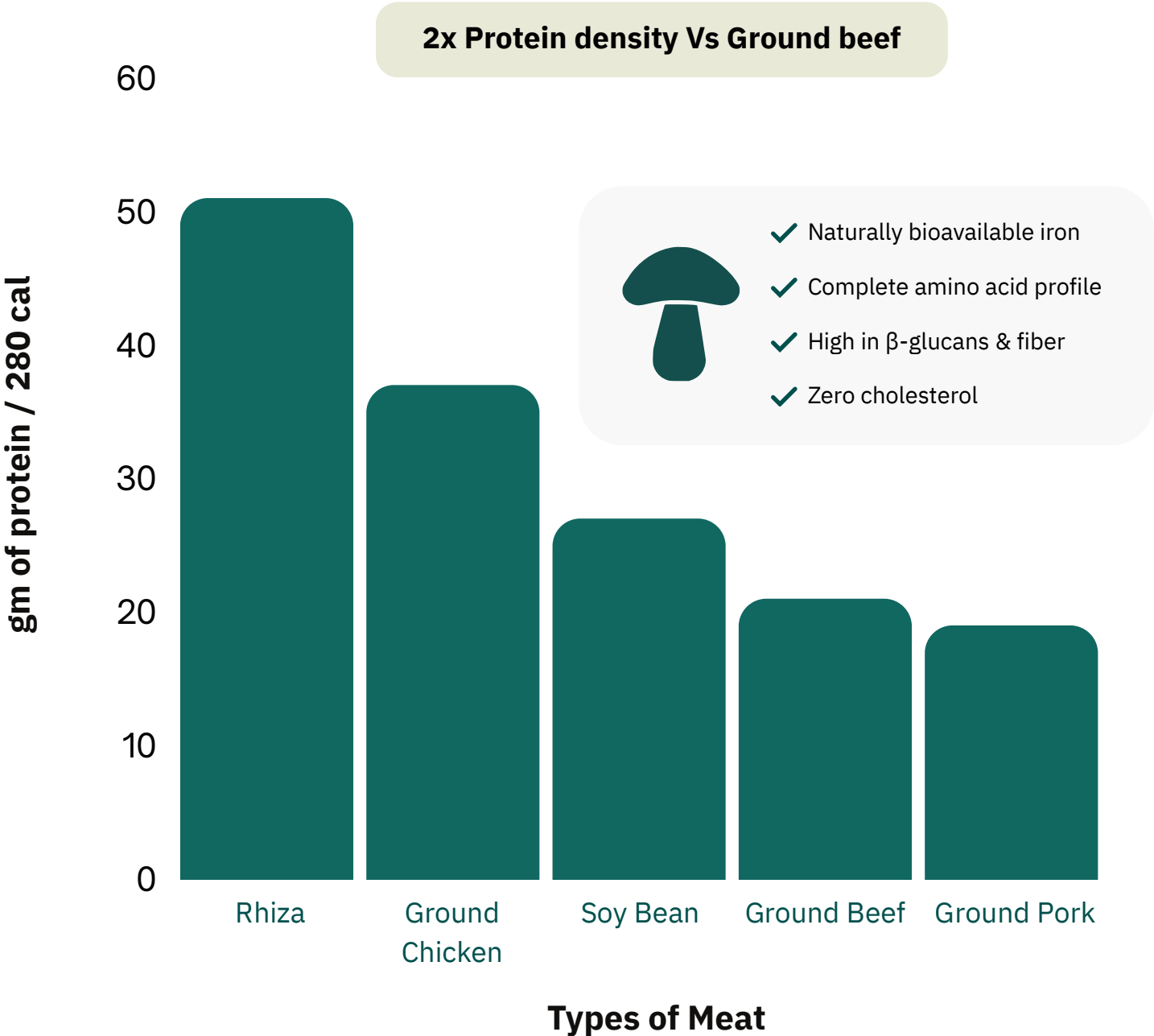
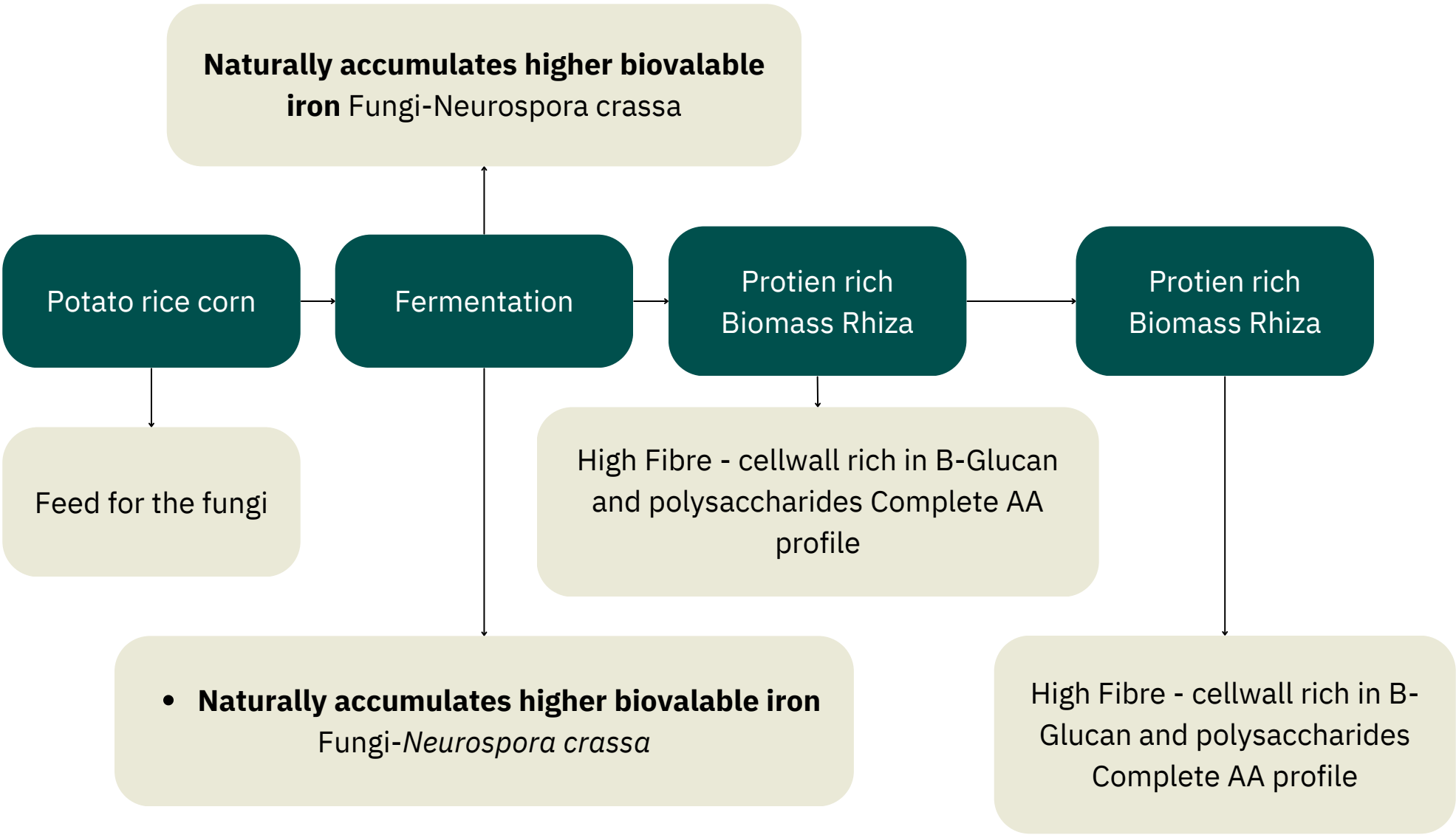
45



Better Meat Co.: Rhiza™ Mycoprotein Elevates Protein and Iron Density



Better Meat Co., a U.S.-based innovator, is unlocking a new frontier in alternative protein through Rhiza™—a mycoprotein produced via filamentous fungal fermentation. Grown on low-cost agricultural feedstocks, Rhiza delivers 2x the protein density of beef per calorie and a full spectrum of essential nutrients, including highly bioavailable iron and fiber-rich β -glucans. Their clean-label process enhances nutritional quality while supporting affordability and scalability—key levers for making alt proteins the default choice.



“Our fungal fermentation platform turns low-cost feedstocks into ultra-nutritious protein—clean, efficient, and scalable”

SMAQO’s 50:50 Mycoprotein–Meat Hybrid Enhance Nutrition While Preserving Familiarity

SMAQO, a pioneering food innovator, has developed a hybrid protein solution that combines 50% fermented fungal mycoprotein with 50% conventional meat. The result is a clean-label product that delivers improved nutritional value—without compromising taste or familiarity.

The innovation leverages proprietary fermentation and downstream processing (DSP) to preserve nutrients and structural integrity across the blend.

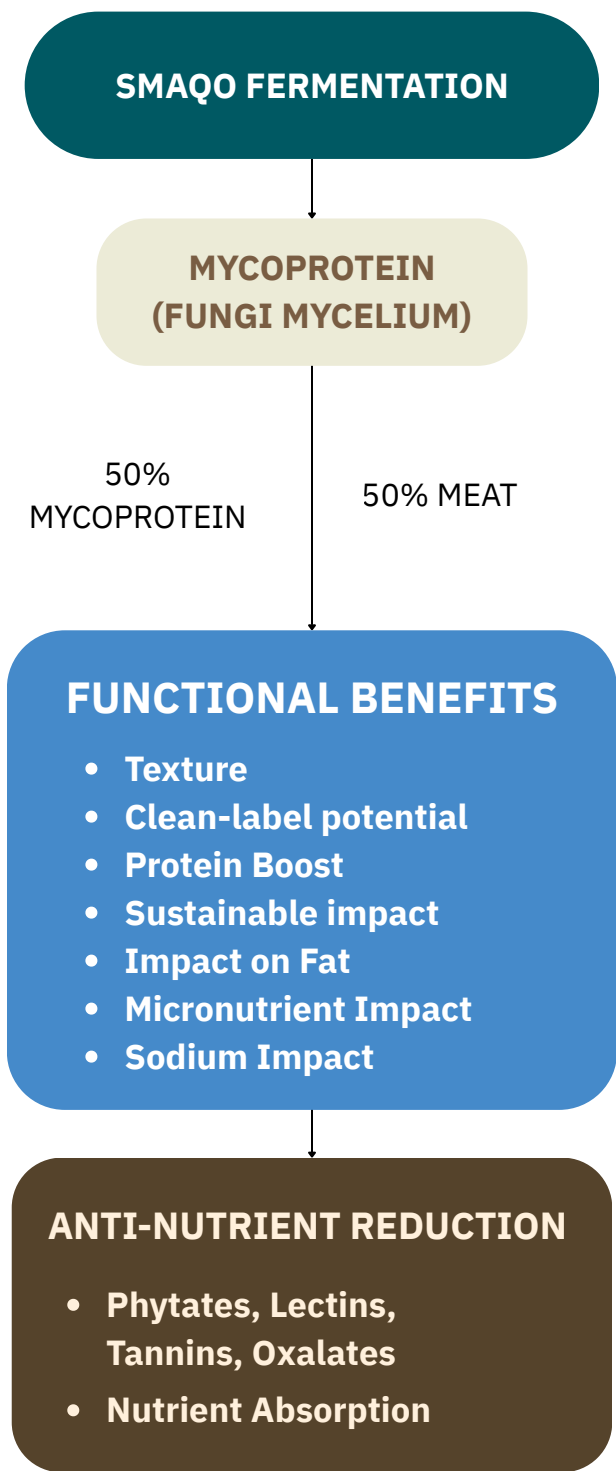
This versatile format—ideal for patties and nuggets—that offers:

- Moisture retention and improved texture
- Complete amino acid profile for better protein quality
- Elevated levels of iron, zinc, and B-vitamins
- Reduced sodium and saturated fat potential

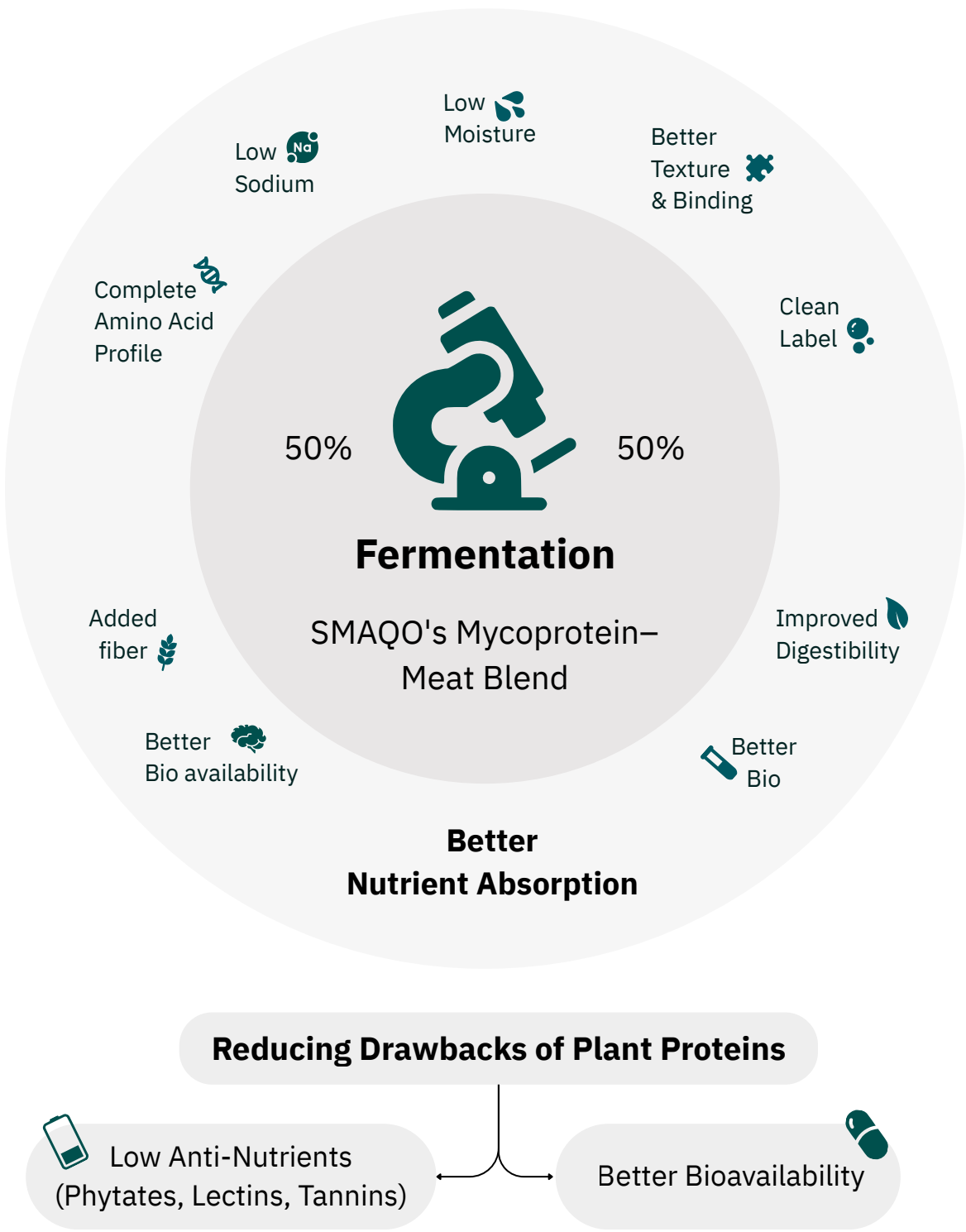
Together, these attributes address key nutritional gaps while aligning with consumer priorities around taste, affordability, and sustainability

SMAQO’s hybrid approach leverages fermentation to deliver functional nutrition benefits across protein, sodium, and micronutrients.

From Fermentation to Function



Functional Benefits



Our fermentation platform enhances nutrient absorption, bioavailability, and taste—without compromising familiarity.

Plantagusto: AI-Driven Nutrition Architecture Elevates Formulation Precision

PLANTAGUSTO

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Plantagusto's **FP3 (Flexible Plant-based Protein Platform)** is a digital formulation engine that blends nutrition, sensory, and clean-label priorities into ready-to-launch product outputs. Powered by proprietary AI trained on bioavailability, nutrient interactions, and ingredient functionality, FP3 helps brands formulate faster while delivering high PDCAAS, low sodium, and optimized shelf life—without sacrificing taste or texture.

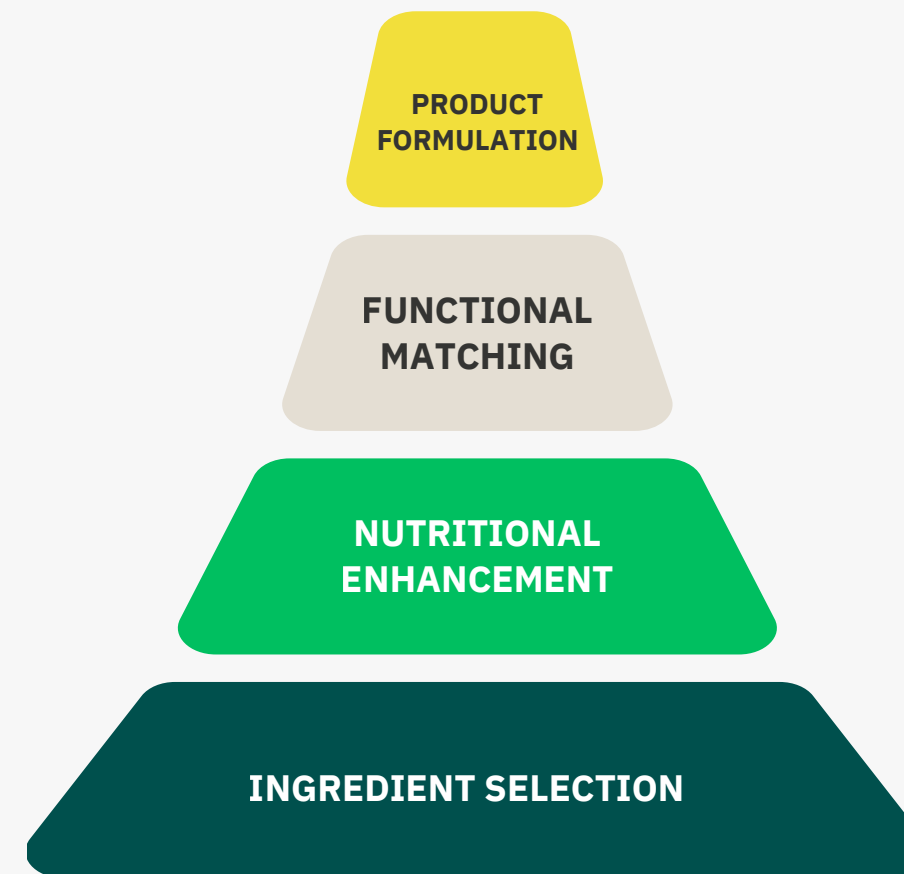
The platform follows a four-layered innovation pathway:

1. Ingredient Intelligence: A database of 1,000+ clean-label ingredients selected for their ability to replicate meat-like function, support nutrition targets, and meet allergen-aware standards.

2. AI-Powered Matching Algorithms Machine learning selects ingredient combinations that meet PDCAAS, sodium, and micronutrient targets—while maintaining texture, emulsification, and cost for clean-label, nutrition-forward formulations.

3. Sensory & Digestibility Modeling: Predictive models evaluate taste, bioavailability, allergen risk, and gut comfort—optimizing for consumer acceptance, FODMAP tolerance, and nutrient synergies like iron–vitamin C pairing.

4. Formulated Product Output FP3 delivers ready-to-deploy formulations for plant-based foods, optimizing nutrition, texture, flavor, and shelf life—supporting clean-label innovation across snacks, meat analogues, and hybrids.



04 | Product Application

03 | Sensory +Digestibility Models

02 | AI Matching Algorithms

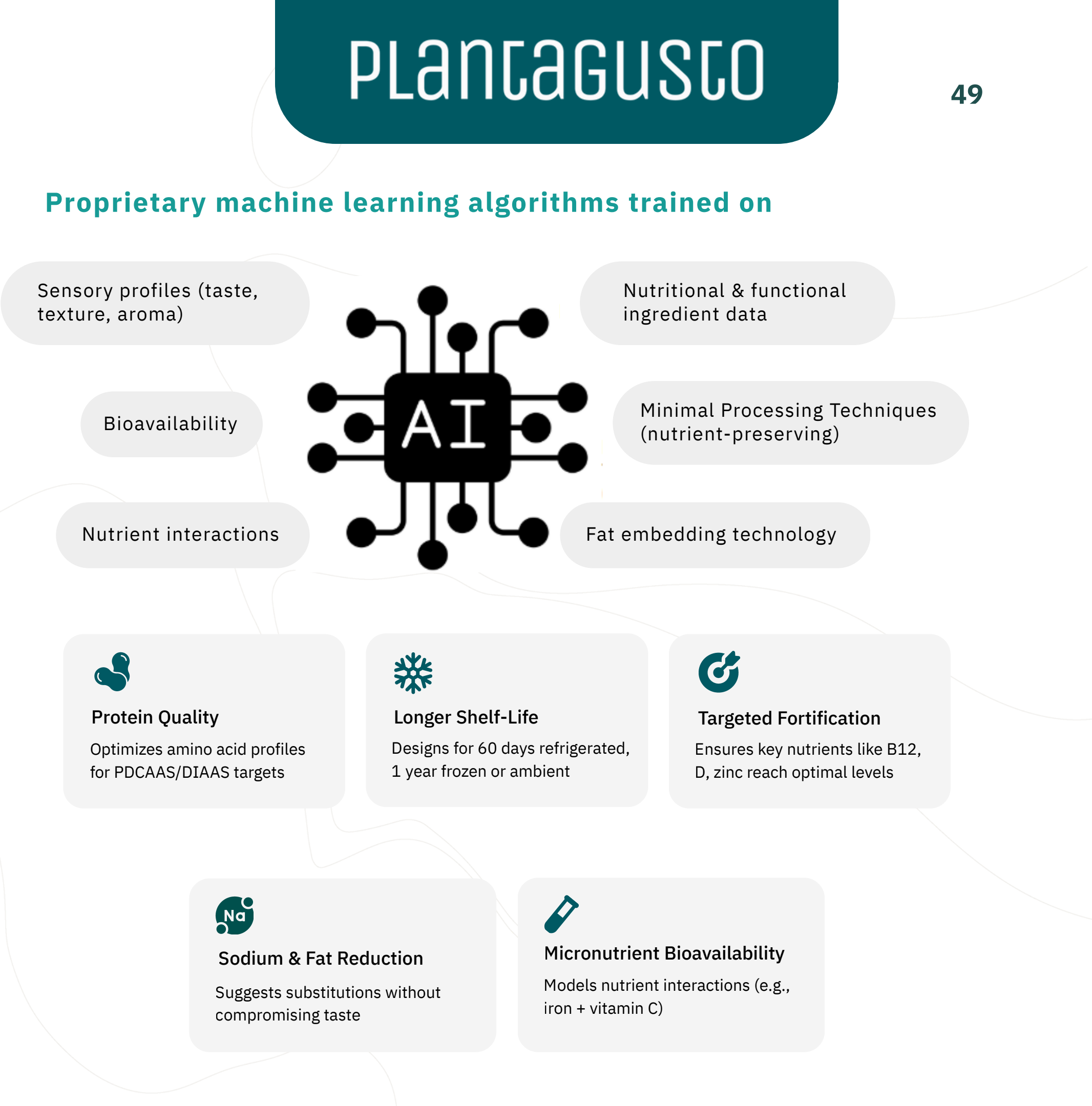
01 | Ingredient DB

Plantagusto: Harnessing AI to Advance Protein Quality, Bioavailability, and Shelf Life

Plantagusto’s FP3 platform doesn’t just mimic meat—it engineers its nutritional architecture, rethinking how fats and proteins are structured in plant-based foods

How Plantagusto Tackles Key Nutrition Challenges

Nutrition Goal	Plantagusto’s Approach
High Protein Density	Optimizes legume/grain blends for amino acid synergy and high PDCAAS.
Low Sodium	Uses umami-rich enhancers and fermentation strategies to reduce salt without taste loss.
Micronutrient Fortification	Selects naturally rich sources of iron, zinc, B12 analogs; models interactions for bioavailability.
Anti-Nutrient Reduction	Avoids high-phytate inputs; integrates processing insights to enhance mineral absorption.
Improved Digestibility	Prioritizes low-FODMAP, gut-friendly ingredients for absorption and tolerance.



Real-World Impact: FP3-Powered Products Are Scaling Across Europe

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Estonia – Veganic

Application: Uses FP3 to supply products across multiple brands.

Result: Demonstrates long-term partnership and flexible output for diverse B2B clients.



Netherlands & Italy – Retail Deployment

Application: Plant-based products formulated via FP3 now launched in local supermarkets.

Result: FP3-backed formulations reach consumers under private-label and emerging brands.

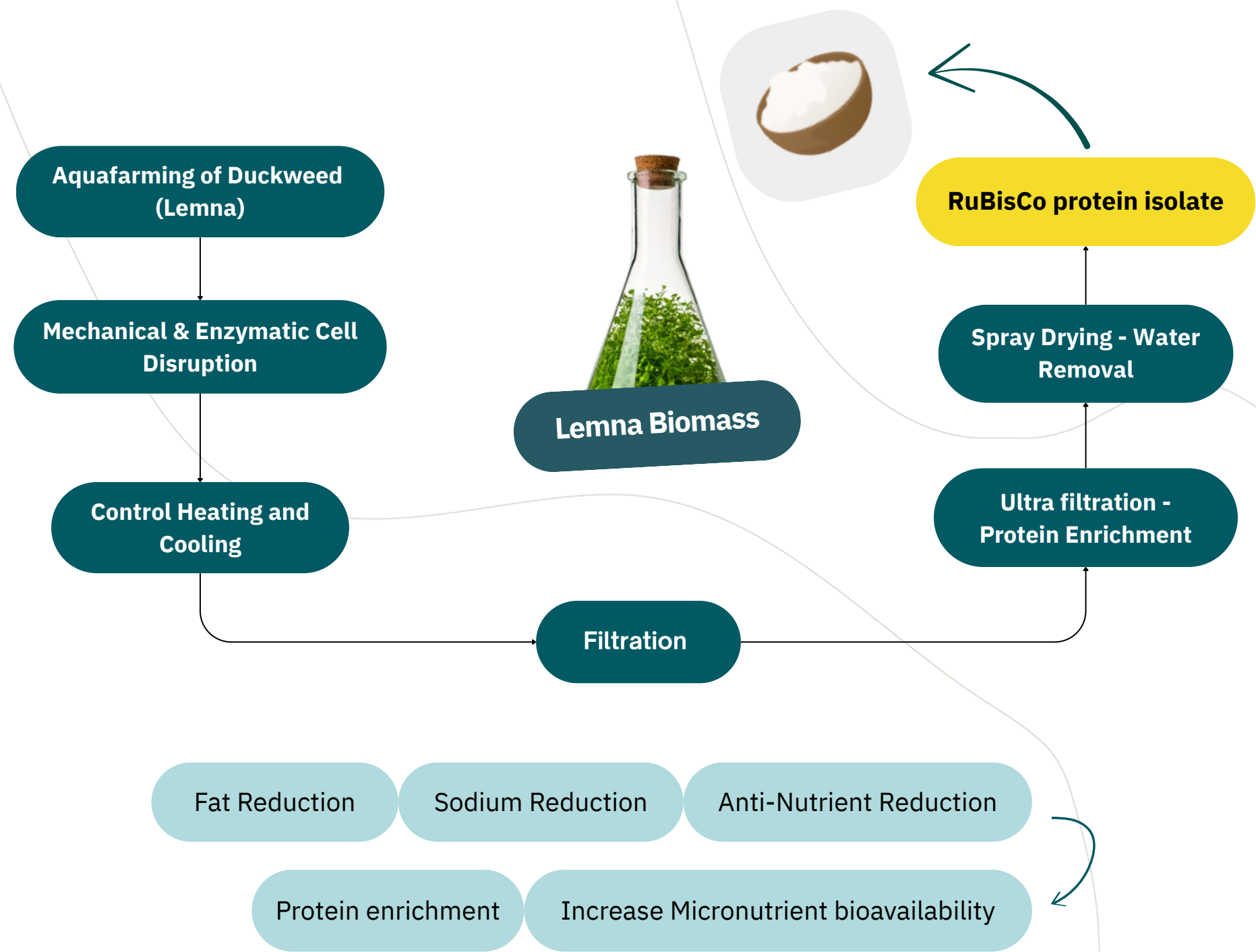


Finland – Hybrid Collaboration

Application: Working with a leading meat manufacturer to develop hybrid products.

Focus: Ground meat analogues with improved taste, nutrition, and processing compatibility.

Plantible: A Scalable, Sustainable Pathway to High-Performance Plant-Based Protein



Plantible's Integrated Extraction Process

Nutritional Advantages of Rubi Protein™

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- **Complete Amino Acid Profile:** It contains **all nine essential amino acids** in optimal ratios for human nutrition, making it a complete protein source.
- **High Digestibility:** With a Digestible Indispensable Amino Acid Score (DIAAS) of 109%, Rubi Protein™ surpasses traditional protein sources like egg, casein, soy, and peas in terms of digestibility and amino acid availability.
- **Superior Protein Yield:** 70% protein, significantly higher than the 27% protein in beef
- **Functional Properties:** Rubi Protein™ exhibits exceptional functional characteristics, including fat-binding capabilities that reduce the need for saturated fats, the ability to form stiff peaks akin to egg whites, and thermo-irreversible gelling properties, making it a versatile ingredient in various food applications.
- **Scalable & Sustainable:** No Arable land use & Lower water usage

Patent Portfolio

🌐 14 global patents, 92% active, cover various aspects of their protein production technology and applications.

📄 Key patent: **WO2021007484A1** (process for high-purity RuBisCO isolation)

Founder Insight

*“Backed by industry giants like **CJ and Kellogg’s**, we’re scaling Rubi Protein™ to meet growing industry demand—even as we navigate the real-world challenges of scale and adoption.”*

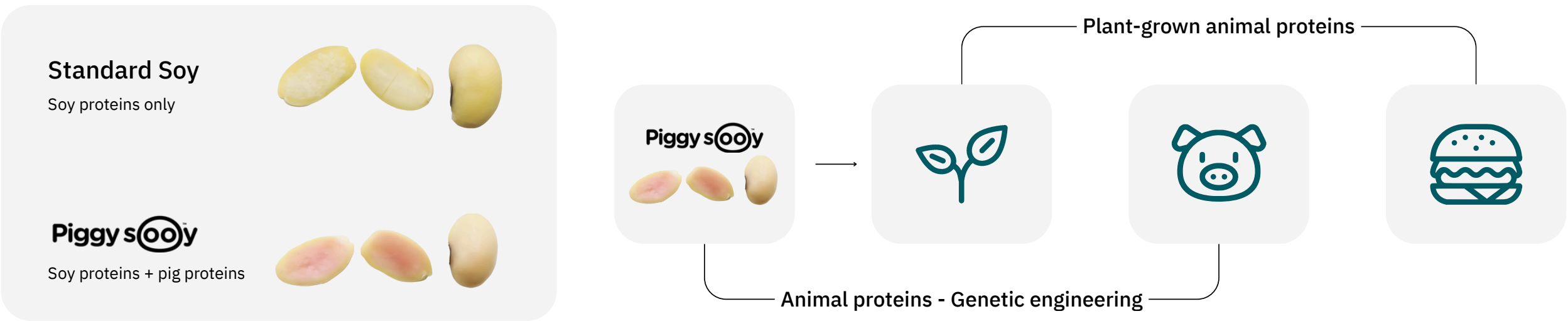
— Tony Martens Fekini, Co-founder, Plantible Foods

Moolec Science: Transforming Plants into Protein Bioreactors

Moolec applies molecular farming to engineer soy, pea, and safflower to express animal-identical proteins within their seeds—eliminating fermentation, enhancing nutrition, and enabling cost-effective scale.

“We’re comparing the plant to a bioreactor—sheer efficiency in lowering the energy trickle down to the protein we need.”

— Henk Hoefnagels, CSO & Co-founder

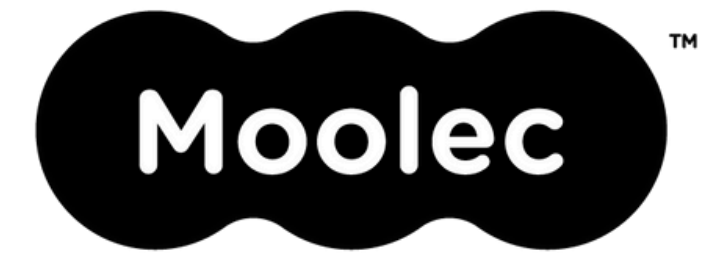


- Piggy Sooy™ is a **soybean modified to express myoglobin**. In this seed, about 25% of the soluble protein content is myoglobin. This loosely translates into about 5-10% of the total bean volume.
- Moolec Science is conducting identity-preserved field trials and expects its largest harvest by late 2025

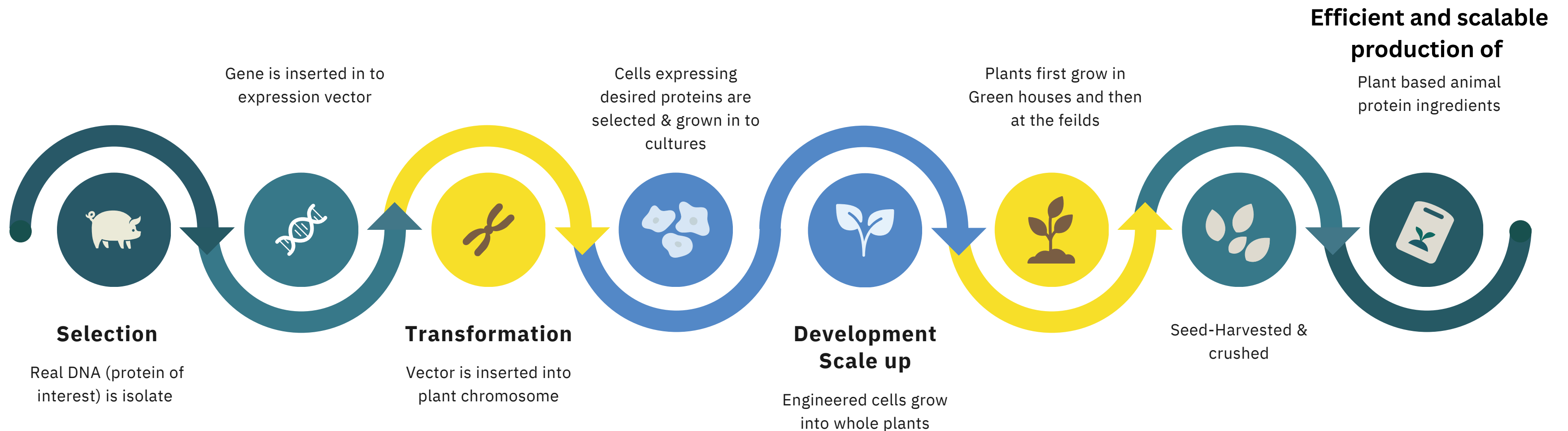
✓ **26.6 % pork protein in soy**

What Sets It Apart

- **Embedded Animal Proteins:** Expresses functional proteins like porcine myoglobin and bovine chymosin directly in plants.
- **Cost & Energy Efficiency:** Leverages existing crop infrastructure to cut costs and eliminate fermentation steps.
- **Regulatory Advantage:** Focused on the U.S. market for its openness to bioengineered ingredients; navigating GMO-related perceptions internationally.
- **Early Market Traction:** Field trials underway; early adoption in pet food; partnerships with soy processors and tofu producers.



Molecular farming in a nutshell



Genetic code, that encodes the protein of interest, is identified from online databased

Source : [Moolec Science](#)

Framework for Evaluating Nutritional Innovation & Application Maturity







This traffic light scoring system provides a structured method to evaluate companies and technologies enhancing the nutritional profile of plant-based meat. It assesses innovations across two dimensions:

- Nutritional impact – contribution to the five core health priorities
- Application maturity– stage of commercial maturity

Together, these scores benchmark the maturity and relevance of innovations across the alternative protein landscape.

Nutritional Impact Scoring

Each solution is assessed across five key attributes—scored from 0 to 5—based on strategy clarity, ingredient or process innovation, and validation via claims or studies.

Score	Color	Interpretation
5	 Green	High-impact innovation with strong validation
4	 Green	Clear nutritional strategy through formulation/process
3	 Yellow	Indirect or moderate impact via base ingredient choice
2	 Orange	Weak evidence, general claims, or partial reformulation
1	 Red	Minimal or no nutritional focus
0	 White	No relevant data or not applicable

How to Interpret This Scoring Table

A directional tool to understand nutritional innovation across technologies. This scoring framework was developed to systematically assess the nutritional potential and commercial maturity of technologies used in plant-based meat—spanning five key nutrition attributes and Application Maturity.

Each score is based on a combination of:

- Desk research on company claims, published studies, and patent filings
- Expert interviews with food technologists, formulators, and academic researchers
- Comparative evaluation of formulation strategies, processing techniques, and validation data

Disclaimer: This analysis is based on publicly available information and qualitative expert input. It is intended as a directional reference—not a definitive ranking or endorsement. Scoring reflects the best interpretation of available data at the time of review and may evolve as new insights emerge.

Score	Sodium Reduction	Lipid Optimisation	Protein Quality	Micronutrient Fortification	Anti-Nutrient Reduction
0	No sodium strategy identified	No lipid-related data	No protein quality data	No relevant micronutrient activity	No mitigation or awareness of antinutrients
1	High sodium content, no strategy	Saturated-fat oils used without modification	Low-quality protein; no digestibility plan	Minimal micronutrient presence; may include inhibitors	High antinutrient residue; no strategy
2	General “low sodium” claim with no reformulation	Uses neutral oils (e.g. sunflower) without clear lipid intent	Incomplete amino acid profile; no improvement strategy	Micronutrients present by chance; no process to improve bioavailability	Some antinutrients present; no mitigation
3	Umami-rich ingredients to enhance salt perception	Avoids saturated fat; isolated use of omega-3s etc.	Complete protein or blend without digestibility optimization	Natural presence only; no bioavailability enhancement	Low antinutrients via base ingredient, no strategy
4	Sodium-sparing strategies (e.g., yeast extracts, seaweed)	Substitution or fermentation to improve lipid quality	Blended or fermented protein with improved bioavailability	Fortified or fermentation-enhanced bioavailability	Process likely reduces antinutrients; no measured outcome
5	Reformulated with salt replacers (e.g., KCl), validated	Advanced structuring (e.g., oleogels, encapsulation)	Complete protein with PDCAAS or DIAAS ≥ 1.0	Targeted fortification + absorption enhancers (e.g., vit C)	Validated antinutrient reduction (e.g., enzyme assays)

Application Maturity Scoring

Each technology was also evaluated for Technology Readiness Level (TRL)—how close it is to being widely adopted in the food system.

Score	Tier Name	Example Interpretation
5	Commercially Proven	Widely adopted, functionally validated, and scaled
4	Technically Deployable	Use cases exist, but not yet mainstreamed
3	Pilot-Ready	Demonstrated in niche launches or R&D pilots
2	Feasibility Stage	Technically promising; faces throughput or scalability barriers
1	Ideation Stage	Conceptual; not yet tested for real-world food application
0	Not Validated	No current real-world application or potential

Why it matters: This scoring system helps benchmark technologies working toward better nutrition in plant-based meat—highlighting not just what’s innovative, but also what’s realistically deployable in today’s market.

Production technology	Additional Process/ Input Innovation steps		Fermentation strain	Application Maturity	Sodium impact	Lipid optimisation	Micronutrient fortification	Protein quality	Antinutrient reduction
Fermentation	Proprietary fermentation (inoculation, strand formation, post-treatment)	cultured soy protein, wheat gluten, coconut oil, bee juice concentrate, salt, iron, vitamin B12	undisclosed strain	●	●	●	●	●	●
	-	Mycoprotein, potato protein, wheat protein.	<i>Fusarium venenatum</i> strain PTA-2684	■	●	●	●	●	●
	-	<i>Neurospora crassa</i> , salt, acacia gum, oat fiber, chickpea flour, lycopene.	<i>Neurospora crassa</i>	●	●	●	■	■	●
	-	Koji culture, yeast, water, rice, konjac root flour, rice bran oil, sea salt	<i>Aspergillus oryzae</i> (Koji mold)	●	●	●	●	■	●
	-	legumes, grains, fungal mycelium	Undisclosed fungal strain	●	●	●	●	●	●
	-	Mycoprotein	undisclosed filamentous fungus	●	●	●	●	●	●
	-	Mycoprotein	<i>Fusarium venenatum</i>	■	●	●	●	■	●
	Fermentation + Spray Drying	pea protein, rice protein, shiitake mushrooms mycelium	Various mushroom mycelia (e.g., shiitake)	●	●	●	●	●	●
	AirMycelium™ platform controlled mycelium cultivation via optimized airflow, humidity, and temperature.	oyster mushroom, wood chips, plant materials	<i>Pleurotus</i> species (e.g., oyster mushroom)	●	■	●	●	●	●

Production technology	Additional Process/ Input Innovation steps		Fermentation strain	Application Maturity	Sodium impact	Lipid optimisation	Micronutrient fortification	Protein quality	Antinutrient reduction
Shear cell processing		soy protein, wheat gluten	NA	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Directional freezing	<ul style="list-style-type: none"> Directional Freezing: Aligns hydrogel channels for fish-like texture Protein Infusion: Soy/pea/gluten form fibrous gel structure Lipid Functionality: Gel enables fat distribution & retention Nutrient Enrichment: Post-freezing infusion with DHA/EPA Customisation: Protein loading adjusted via time & concentration 	agar, carrageenan, guar gum, soy protein, pea protein, wheat gluten	NA	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Fermentation + Extrusion	<ul style="list-style-type: none"> Fermentation: GE yeast (<i>P. pastoris</i>) produces soy heme Extrusion: HME structures soy protein into meat-like fibers Fortification: Heme, zinc, B1, B3, B6, B12 Benefit: Enhanced bioavailability via heme iron 	pea protein, oat protein, sunflower seed protein, rapeseed oil, vitamin B12	undisclosed strain	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
		soy protein, chiickpea, mushroom, vital wheat gluten, potato, coconut oil	undisclosed strain	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
		soy	<i>Komagataella phaffii</i> (formerly known as <i>Pichia pastoris</i>)	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
		seaweed, alagae (spirulina)	undisclosed strain	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>
Minimal processing	Shiitake mushroom ferments pea and rice protein to result in complete protein with high digestibility	shiitake mushrooms, pea protein, rice protein	NA	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>	<div></div>

Contributors:



ALTRUISTIC INNOVATIONS

Connecting the like-minded for a sustainable future

Altruistic Innovations is a purpose-driven consulting platform advancing food and biotech innovation across Asia. Led by Sruthi Sadanand, the firm brings deep expertise in alternative proteins, product development, and strategic foresight.

As the lead consultant for this report, Altruistic Innovations spearheaded the end-to-end research and analysis—from methodology design to execution—working closely with founders and industry experts to map technologies and companies shaping the nutritional future of plant-based meat.



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Thinking Forks is a global food-tech R&D consultancy with expertise in product innovation, strategy, and commercialization across the food industry.

As a supporting partner, Thinking Forks was involved across multiple phases of this project, contributing to early-stage desk research, company mapping, and contextual insights. Their experience across Asian and global food systems added depth to the foundational stages of this work.

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Headquartered in Singapore, **the Good Food Institute Asia Pacific (GFI APAC)** is part of a global network of alternative protein think tanks spanning seven regions. We advance a more secure, sustainable, and just food system through open-access R&D, corporate engagement, and public policy.



Thank you!

Have any questions or notice any missing or incorrect
information about your organization?

Get in touch with us: **apac-scitech@gfi.org**