



Microbiome intelligence as operational infrastructure

Structuring deployment and competitive advantage in European food systems through MICROORC.

Turning biological insight into measurable performance across European food systems.

Redefining value through microbiome intelligence

European food systems are entering a decisive phase where value creation is increasingly shaped by managing biological variability across supply chains. **In 2022, food waste in the European Union reached 59.2 million tonnes, equivalent to 132 kg per capita**, reflecting persistent inefficiencies in shelf-life estimation, spoilage management, and cold-chain performance. These inefficiencies continue to erode margins across manufacturing, retail, and distribution layers.

Microbiome intelligence is now moving beyond research into a system-level capability within food operations. Through the MICROORC project, funded by the European Union under Horizon Europe (Grant Agreement 101136248), PNO Innovation applies a structured methodology combining ecosystem mapping, funding intelligence, patent analysis, and market assessment. With technology maturity concentrated at Technology Readiness Levels 4 to 7, this approach identifies where biological insight can be deployed to deliver measurable value.

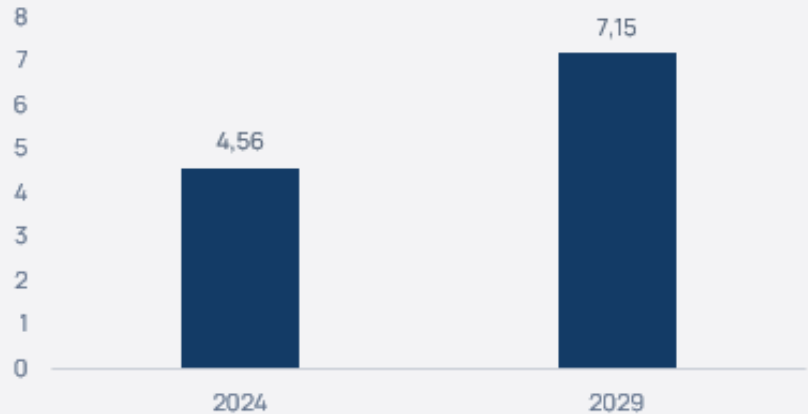
Microbiome intelligence is becoming a determinant of performance, margin stability, and system efficiency. The question is no longer whether it works, but where it delivers the greatest value.

A market transitioning to data-driven food system control

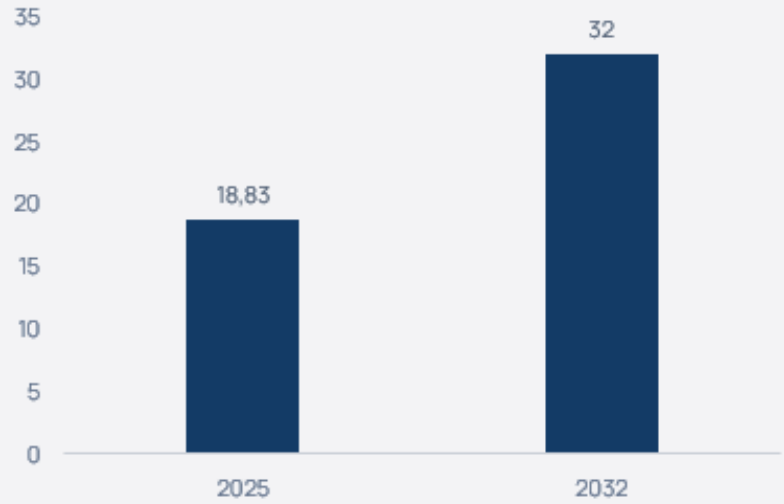
The European food innovation landscape is structuring around the convergence of predictive shelf-life estimation, microbiome-based diagnostics, and active and intelligent packaging. These domains form a unified operational layer, enabling continuous and data-driven quality management across the food value chain.

Market expansion reinforces this structural shift. The global shelf-life testing market is projected to grow from approximately USD 4.56 billion in 2024 to USD 7.15 billion by 2029, representing a compound annual growth rate of 9.5%. The global food diagnostics market is expected to reach USD 32 billion by 2032. In parallel, the active, smart, and

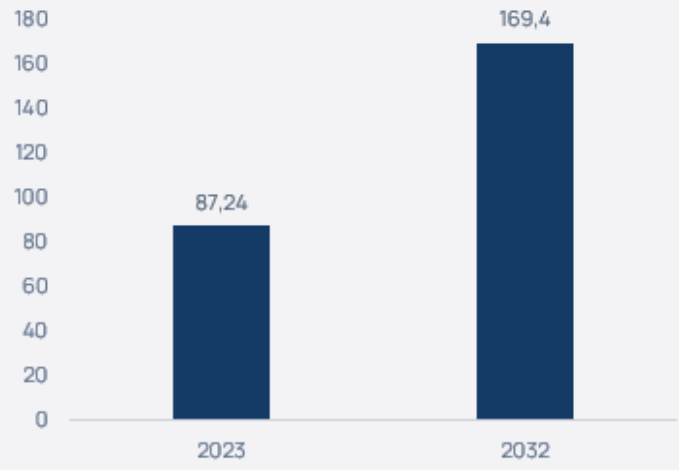
intelligent packaging market is forecast to expand from USD 87.24 billion in 2023 to USD 169.4 billion by 2032, corresponding to a compound annual growth rate of 6.9%.



Global food shelf-life testing market by value (\$b)



Food diagnostics market by value (\$b)



Active, Smart and Intelligent Packaging Market by value (\$b)

Static, laboratory-based testing is replaced by integrated approaches combining predictive modelling, real-time sensing, and bio-integrated preservation. Competitive differentiation is defined by the ability to deploy these capabilities within existing quality, logistics, and packaging systems.

Market convergence is transforming food quality management into a continuous, data-driven system.

From insight to deployment: structuring system-level adoption

Realising the value of microbiome intelligence depends on aligning strategy, investment, and execution. MICROORC demonstrates that organisations achieve impact when these dimensions are coordinated, enabling the transition from innovation to deployment. PNO Innovation leads this process, enabling stakeholders to translate insight into outcomes.

This approach—seen across leading European initiatives—integrates four interdependent elements:

- » **Vision and Strategy** – Set evidence-based priorities aligned with operational outcomes and policy direction
- » **Financing and Support** – Mobilise public and private investment to accelerate responsible innovation.
- » **Execution and Governance** – Ensure transparent collaboration and compliance throughout deployment.
- » **Digital Leverage** – Use analytics and infrastructure to scale impact and measure results.

Together, these elements provide a pathway for transitioning towards integrated, data-driven food system operations, linking technology with regulatory and investment frameworks.

Transformation happens where evidence, investment, and execution converge.

Case examples in action

MICROORC is actively embedded in European innovation ecosystems, translating microbiome intelligence into collaborative, cross-sector initiatives that accelerate adoption across food value chains.

- » **Microbes4SustainableFoods cluster:** MICROORC contributes to this Horizon Europe cluster, aligning with complementary projects to advance microbiome-driven innovation in sustainable food systems and strengthen cross-project synergies.
- » **Industry and research engagement:** Through participation in targeted workshops, conferences, and stakeholder events, MICROORC connects with food producers, technology providers, and policy actors to align innovation with operational and regulatory needs.
- » **Cross-project collaboration and knowledge exchange:** The project engages with related European initiatives to share methodologies and insights on predictive modelling, diagnostics, and sustainable packaging, supporting convergence across emerging technology domains.

Collectively, these initiatives demonstrate how data transparency, shared infrastructure, and policy alignment convert research investment into measurable value.

When collaboration meets insight, innovation scales from pilot to system-level impact.

Are you ready to revolutionise your strategies and establish a market-leading position in microbiome intelligence in food systems?

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Ecosystem positioning in a structuring innovation landscape

PNO Innovation's analysis within MICROORC provides a structured view of the European ecosystem, comprising more than **650 organisations, 41 R&D&I programmes, and €2.472 billion in private capital flows between 2018 and 2024**. By integrating funding intelligence, patent screening, and stakeholder mapping, this analysis identifies where research, investment, and deployment converge across the value chain.

Technology maturity is concentrated at Technology Readiness Levels 4 to 7, supported by **€113.2 million in public funding and 913 European patent families, with peak activity observed in 2023**. These indicators signal a transition from experimental validation towards deployment readiness and highlight increasing consolidation around actors capable of system integration.

Ecosystem concentration and capital alignment indicate a clear shift from innovation activity to deployment economics.



Operationalising microbiome intelligence across food systems

MICROORC identifies five control layers shaping microbiome-enabled food systems, translating biological insight into actionable decisions across the value chain:

- » Predictive shelf-life modelling, enabling reduction of losses linked to conservative expiry dating
- » Rapid spoilage-risk diagnostics, reducing exposure to recalls and quality deviations
- » Smart sensing and labelling, reducing information asymmetry across supply chains
- » Microbiome-based biosolutions, reducing dependency on chemical preservation strategies
- » Packaging-integrated control systems, mitigating the impact of environmental variability on product stability

Value is realised through deploying these layers across processing, logistics, and quality-control systems, supporting cost control, waste reduction, product stability, and regulatory alignment under real-world conditions.



From innovation maturity to market advantage

The competitive frontier is shifting from innovation ownership to deployment capability. Organisations integrating microbiome solutions into enterprise systems, logistics processes, and packaging design are best positioned to convert technological maturity into measurable advantage.

Sustained capital allocation and rising patent activity reinforce the importance of validation and deployment pathways. As these capabilities become standard practice, organisations that remain confined to isolated research risk structural cost exposure and declining competitiveness.

Deployment—not standalone innovation—defines the next generation of competitive advantage.



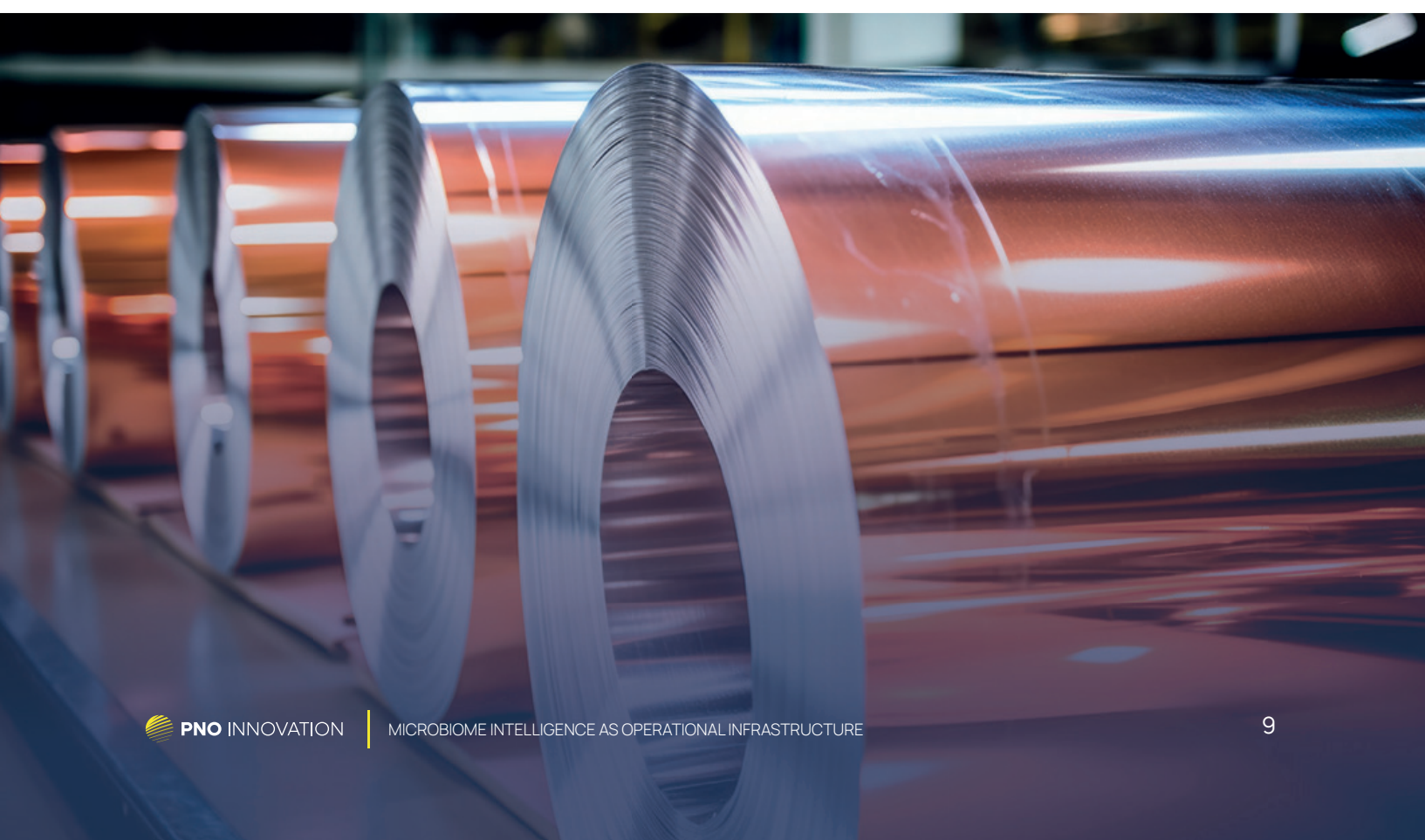
Strategic priorities for system-level adoption

The convergence of capital allocation, regulatory expectations, and technological maturity is accelerating system-level adoption. Microbiome intelligence is becoming embedded within European food system infrastructure, shaping how quality, risk, and value are managed.

For decision-makers, three priorities are clear:

- » Deploy microbiome intelligence within operational decision systems to capture measurable value
- » Align implementation with evolving quality and regulatory frameworks to ensure compliance and trust
- » Leverage system integration to stabilise margins and reduce inefficiencies across perishable value chains

Competitive advantage will be defined by the speed and precision of deployment.



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