National Biofilms Innovation Centre

BIOFILM ALLIANCE
Regulatory Science Network

FOOD SAFETY RESEARCH NETWORK

Biofilm Methodologies and Food Sector Regulation

WORKSHOP REPORT

6 MARCH 2025, NOTTINGHAM UK

Contents

BIOFILM METHODOLOGIES AND FOOD SECTOR REGULATION

Executive Summary

This report summarises the outcomes of a cross-sector workshop on Biofilm Methodologies and Food Sector Regulation, held in Nottingham on 6 March 2025, organised by the National Biofilms Innovation Centre (NBIC), the Biofilm Alliance and the Food Safety Research Network (FSRN). The workshop brought together stakeholders from industry, academia, regulatory bodies, and testing organisations to discuss the challenges that microbial biofilms pose across the food supply chain. The participants were asked to discuss the following points:

- What biofilm methodologies is the food industry currently using to meet regulatory requirements?
- What are the challenges and needs in addressing biofilms in the food sector?
- What challenges arise when navigating the UK's food regulatory landscape?
- What solutions could be proposed to address the above difficulties?
- What additional methodologies or guidelines would the industry like to see developed to further support regulatory compliance?

Key discussions revealed that biofilms remain a widespread but under-recognised risk in food production environments. Many organisations lack awareness, education, technical expertise, and the resources needed for effective biofilm detection, prevention, and intervention. Current detection tools, such as swabbing and reactive sprays, are inconsistent, non-quantitative, and often fail to identify early-stage or embedded biofilms.

Participants agreed that prevention is more effective and cost-efficient than remediation. Practical strategies include tailored, multistage cleaning protocols; condition monitoring; hygienic equipment design; and the use of advanced technologies such as enzymes, UV light, and biocontrol agents. However, adoption remains uneven due to gaps in regulatory guidance, limited small and medium enterprises capacity, and insufficient validation of emerging tools.

The absence of a biofilm-specific regulatory framework was identified as a major barrier. Existing standards (e.g. HACCP) do not reflect the complexity of biofilm risks. Retailers often impose their own requirements, leading to inconsistency across the sector. There is a clear need for standardised methodologies, industry-specific definitions, and collaborative frameworks to guide action.

Proposed next steps for the scientific and industry communities include developing validated detection tools, enhancing workforce training, creating shared knowledge platforms, and aligning regulatory and industry practices. A coordinated, proactive approach would be essential to strengthen food safety, support innovation, and build long-term resilience against biofilm-related contamination risks.

Background

BIOFILMS IN CONTEXT

Biofilms in the food sector can present a considerable challenge to food safety and management of microbial risk throughout the entire supply chain, from farm to fork. Biofilms are structured communities of microorganisms that attach to other microorganisms or surfaces and become embedded in a self-produced matrix, enabling them to survive in a wide range of environments, including irrigation systems, food processing equipment, and storage units. On farms, biofilms can harbour harmful pathogens such as Salmonella and Listeria, contaminating equipment and being associated with crops and livestock. In food processing facilities, they are especially difficult to remove due to their resistance to cleaning agents, with the potential to persistently contaminate machinery and surfaces. Even at the retail and consumer stages, biofilms on surfaces such as cutting boards or packaging materials can contribute to food spoilage and the risk of foodborne illness. Their presence across the food supply chain highlights the importance of rigorous hygiene practices, effective cleaning regimes, and continuous monitoring, as reinforced by the UK Food Standards Agency's guidance under Regulation (EC) No. 852/2004 on the hygiene of foodstuffs, which remains retained UK law post-Brexit. Additionally, compliance with the Food Safety and Hygiene (England) Regulations 2013 and regular adherence to Hazard Analysis and Critical Control Point (HACCP) principles are essential to ensure food safety and control biofilm risks across all stages of food handling and production.

NATIONAL BIOFILMS INNOVATION CENTRE (NBIC)

NBIC was formed in December 2017 as an Innovation and Knowledge Centre (IKC) funded by BBSRC and Innovate UK, with a mission to harness the UK's industrial and academic strength in biofilms. NBIC is led by four lead universities (Edinburgh, Liverpool, Nottingham and Southampton).

NBIC is the recognised UK hub for accessing biofilm expertise, capability, science, and innovation capacity. Its aim is to catalyse growth in the UK's scientific, technological, and industrial expertise in biofilms with the goal of delivering:

- World class science and scientists.
- Breakthrough innovations.
- Economic and societal value.

NBIC is working to create a network and community of researchers and industrial/commercial partners, across the UK and internationally, who together are working to progress all these elements.

BIOFILM ALLIANCE

The Biofilm Alliance is an initiative funded by Innovate UK to create a transformative network dedicated to tackling the global challenges posed by microbial biofilms. The network is led by four partner organisations, including National Biofilms Innovation Centre, Manchester Metropolitan University, Industrial Microbiological Services Limited and Swansea University.

By bringing together experts from academia, industry, metrology, regulatory bodies, and standardisation organisations, the Biofilm Alliance aims to bridge the gap between state-of-the-art research and effective regulation, promoting collaboration and fostering innovation in biofilm mitigation and control technologies.

Biofilm Alliance focuses on four broad industry areas, where biofilms pose significant challenges:

- Industrial Processes: Addressing the impact of biofilms on manufacturing efficiency and contamination risks.
- Water Systems: Tackling biofilm formation in drinking water, wastewater treatment, wet leisure, and industrial water applications.
- Food: Managing biofilm risks in food production, processing, storage, and packaging.
- Built Environment: Understanding and mitigating the impact of biofilms in buildings and infrastructure.

FOOD SAFETY RESEARCH NETWORK

The UK Food Safety Research Network (FSRN) connects food industry, food and health policymakers and academia to collaboratively pursue shared research priorities that will protect the UK from foodborne hazards.

The network is hosted by Quadram Institute, funded by Biotechnology and Biological Sciences Research Council (BBSRC) and the Food Standards Agency (FSA), and serves as an innovation hub to coordinate and fund cross-sectoral research and training activities that address current and emerging challenges.

FSRN's objectives are to:

- Assemble a community of UK food producers, food policy makers and scientific researchers who collectively can take robust actions toward improving food safety.
- Identify areas of research need and opportunity that, in the view of food stakeholders and network members, will have meaningful impacts on UK food safety.
- Coordinate new collaborative research activities that will promote the application of science towards the food safety challenges identified by our food system community.
- Host training to promote skills development, interoperability and relationship-building between our food system community.
- Translate the knowledge generated within the network to food safety stakeholders, and to upcycle existing information and technologies relevant to food safety that have not yet been applied more broadly.

FSRN works across four priority areas of:

- Reducing microbial risk of known pathogens.
- Understanding and navigating risks in the novel and unknown.
- Applying food safety knowledge and technology to traditional practices to reduce risk.
- Food safety in the home.

Workshop on Biofilm Methodologies and Food Sector Regulation

SETTING AND AIMS

The workshop was held in Nottingham on 6 March 2025.

Representatives from academia, metrology institutions, regulatory bodies, and the food industry, spanning the entire supply chain from farm to fork, were brought together to discuss current practices, needs, trends, and expectations regarding biofilm methodologies used within the UK food sector, and to foster active participation from both industry and regulatory stakeholders to guide future developments in this area.

The intended outputs were:

- To create discussion summary notes for distribution to all attendees and for wider dissemination.
- To identify next steps for the Biofilm Alliance, NBIC and FSRN, as well as the food industry, regulators and academic community, towards consensus and standardisation of biofilm methodologies, and to influence future regulation in the food sector.

To provide input and candid and informative discussions during the meeting, all delegates were asked to consider and debate the following questions:

- What biofilm methodologies is the food industry currently using to meet regulatory requirements?
- What are the challenges and needs in addressing biofilms in the food sector?
- What challenges arise when navigating the UK's food regulatory landscape?
- What solutions could be proposed to address the above difficulties?
- What additional methodologies or guidelines would the industry like to see developed to further support regulatory compliance?

DISCUSSION

The delegates were divided into 4 groups, each having a mix of representatives from different disciplines (industry, academia, metrology, regulations) for focused discussions around the predefined questions and to identify the main priorities and next steps. The main themes that emerged from the discussions at the workshop are summarised below:

Biofilm Awareness in the Food Sector

CURRENT STATE

- Understanding of biofilms within the food industry is still relatively new and developing. Although scientific knowledge and technical solutions are progressing, awareness across the sector remains inconsistent. Some parts of the industry do not yet recognise biofilms as a significant challenge, which results in underinvestment in monitoring, prevention, and intervention strategies.
- The term "biofilm" remains unfamiliar or misunderstood by many in the workforce, particularly in SMEs where technical capacity can be limited. With a general lack of awareness, workforce education and mentoring are urgently needed to improve understanding of biofilms, contamination risks, and intervention strategies. For example, based on their own expertise and experiences, engineers and technical managers may understandably focus on mechanical functionality rather than microbial risks, making it difficult to identify contamination vulnerabilities. Similarly, many auditors and Environmental Health Officers (EHOs) can take the view on overall compliance or may focus on food standards relating to specialisations other than microbial risk, rather than being an advocate and agent of meaningful microbiological improvement.

CHALLENGES AND BARRIERS

Several barriers hinder effective biofilm management in the food sector:

- A general lack of awareness and advocacy for biofilm-related issues.
- Loss of institutional knowledge due to retirements and high staff turnover.
- Poor visibility and limited sharing of contamination incidents across the sector.
- High diversity of biofilms in terms of composition, structure, and impact, complicating standardised responses.
- Some businesses and SMEs face difficulties due to limited expertise, insufficient staff training, and resource constraints that limit the adoption of improved practices. In contrast, other SMEs have specialist knowledge on biofilms based on their product profile, where knowledge and experience of microbiology may be heightened (e.g. dairy).
- A lack of a consistent definition of what constitutes “clean” in the context of biofilm prevention, creating uncertainty around both operational and regulatory expectations.
- The complexity of data from advanced diagnostics (e.g. metagenomics) which often fails to translate into practical interventions at the company level.

PROPOSED SOLUTIONS

To overcome these barriers, several strategic solutions have been proposed:

- Promote biofilm advocacy through networks, industry champions and trade organisations, and regulatory bodies.
- Close generational knowledge gaps via formal training, CPD programmes, and structured mentoring schemes.
- Mitigate “brain drain” by creating knowledge hubs, documenting best practices, and preserving the expertise of experienced staff.
- Develop open-access platforms for sharing information on biofilm risks, prevention, and control.
- Deliver education and training through certified courses, CPD-accredited modules, and industry-linked apprenticeships or degree schemes.
- Create biofilm-specific decision-support tools, including tailored decision trees for retail and manufacturing settings to guide detection and intervention efforts.
- Support fundamental research into biofilm ecology in food environments and translate findings into simplified tools for non-specialists.
- Encourage cross-disciplinary collaboration between microbiologists, engineers, and operational staff to foster integrated, practical solutions.

Regulatory Landscape and Standards for Biofilm Management in the Food Sector

CURRENT STATE

- There are currently no specific regulations that target biofilms directly. However, food businesses are legally required to produce safe food and maintain a robust environmental monitoring plan, which implicitly includes the management of biofilm risks.
- In the United States, ASTM methods are widely used and can become embedded into legislation, forming part of enforceable regulatory requirements. In contrast, ASTM methods are not formally accepted within the UK regulatory framework, which differs significantly. Biofilm-related ISO standards presently focus more on sectors such as agriculture and healthcare, with limited relevance to food processing. This highlights the need to align or adapt these standards to better reflect the specific challenges of the food sector.
- In the UK and Europe, most standards function as guidance or recommendations rather than legally binding legislation. This creates a different regulatory dynamic from the US and underscores the need for clearer integration of biofilm-specific standards into UK food safety practices.
- The existing HACCP (Hazard Analysis and Critical Control Points) framework is over 30 years old and not aligned with modern microbiological testing or data capabilities. There is a pressing need for updated regulatory guidance that incorporates new detection tools and microbial understanding.

CHALLENGES AND BARRIERS

- The absence of a unified regulatory framework for biofilms in the food sector can create confusion and inconsistency. Barriers include:

□ The diversity of stakeholders,
□ High costs associated with purchasing standards,
□ Complexity in implementation,
□ Accreditation challenges.

- Although hygiene standards and microbial thresholds exist for pathogens such as *Salmonella* and *Listeria* (e.g. CFU limits), regulatory guidance on biofilms specifically remains unclear. Retailers often enforce their own risk-based protocols, which may exceed or differ from statutory requirements.
- There is no universally agreed threshold that defines when a biofilm poses a regulatory or operational issue. The inherent heterogeneity of biofilms, in terms of species composition, structure, and location, makes standardisation particularly difficult.
- Biofilm control efforts are also hindered by:

□ A lack of real-time, quantitative monitoring tools,
□ Absence of clear guidance on where and how to sample effectively,
□ Limited data on stage-specific intervention effectiveness.

- Broader systemic challenges include regulatory uncertainty, financial risk, and the slow pace of translating research into practical, usable solutions. There is a recognised need for context-specific data and decision-support frameworks, as well as a centralised knowledge hub to guide both operational and regulatory practices.

PROPOSED SOLUTIONS

A clear and functional definition of "biofilm" in the context of the food sector is essential. This definition should inform standardisation efforts, risk assessments, diagnostic strategies, and regulatory frameworks, and distinguish persistent biofilms from transient contamination.

A number of actionable ideas were proposed:

- Develop and disseminate a regulatory roadmap, potentially led by Campden BRI and circulated via BSI/ISO newsletters or equivalent industry channels.
- Consider adopting a marketing-driven model, such as a "subscribe to open" approach, for distributing regulatory guides in an accessible and sustainable manner. Access to clear, practical regulatory guidance can be a challenge for many food businesses, especially small businesses, which often lack the resources to engage with complex or paywalled information. Such model would allow open access to essential regulatory content, funded through stakeholder subscriptions or sponsorship.
- Explore an "AMR readiness insurance" model that incentivises proactive hygiene planning and biofilm control efforts. This approach would aim to encourage organisations, including particularly those in food sector to implement robust hygiene and biofilm management strategies and training before outbreaks or resistance issues emerge, shifting the focus from reactive to preventative measures.

In developing new guidelines or standards, it is critical that they are both realistic and implementable, particularly for SMEs. Standard-setting processes must be transparent and inclusive, free from disproportionate influence by large corporations, and reflective of the diverse needs of the food industry.

PROPOSED MULTI-STAKEHOLDER FRAMEWORK

A coordinated, cross-sector framework was recommended, involving:

- Government – to provide policy support, funding, and strategic coordination.
- Regulators – such as HSE, ECHA, and FSA, to clarify regulatory expectations.
- Test providers/ laboratories – to offer accredited, standardised testing services.
- Trade associations – to promote industry participation and disseminate best practices.
- Education providers – to deliver training, CPD, and awareness programmes.
- Manufacturers and designers – to embed hygienic design into equipment from the outset.
- Foresight planning – to anticipate emerging risks, such as tolerance or resistance to current biocidal chemistries.

Finally, a push for standardised methods for biofilm detection, monitoring, and control is critical. Harmonisation across the industry would support regulatory alignment, benchmarking, and improve overall food safety outcomes.

Industry Perspectives on Biofilms in the Food Sector

CURRENT STATE

- Understanding of biofilms within the food industry is still relatively new and developing. While scientific knowledge and technical solutions are progressing, industry-wide awareness remains inconsistent. Some segments of the food sector do not yet recognise biofilms as a significant challenge, leading to underinvestment in monitoring, prevention, and intervention strategies.
- The responsibility of inclusion of biofilms in environmental hygiene management systems lies with industry to develop tailored control strategies and to identify high-risk areas, particularly those that can lead to post-cook contamination.
- The food industry aims to be a leader in food safety, reflecting a commitment to excellence and building trust with customers.

Applied standards and testing regimes are driven mostly by retailers (i.e. business to business):

- Microbiological thresholds are often defined by retailers, particularly for end-of-life/shelf-life testing.
- Formal guidance is also provided by standards bodies such as Brand Reputation Compliance Global Standards (BRCGS) and trade bodies such as Chilled Food Association (CFA), which influence environmental monitoring and hygiene expectations.
- High care ingredients, which do not undergo further thermal treatment, are subject to more intensive testing protocols. Suppliers of low care ingredients are expected to meet enhanced requirements, reflected in CFA's updated MGG4 (Microbiological Guidance for Growers).

Since due diligence obligations fall on industry, it is generally seen as preferable for the sector to self-regulate.

- Many companies are already taking ownership of risk management and supply chain controls, building internal protocols to manage microbial threats.
- It was acknowledged that many UK food businesses are small or medium enterprises (under 250 staff) and often lack in-house microbiological expertise. Laboratory tests are frequently used to "tick the box," with results not fully interpreted or understood.

In these settings, technical teams are often viewed as a cost, rather than a value-add, undermining the implementation of preventive microbiological controls.

CHALLENGES AND BARRIERS

- Some SMEs face particular difficulties in biofilm management due to:

□ Limited technical expertise,
□ Lower levels of staff training,
□ Resource constraints that affect the adoption of enhanced monitoring and cleaning practices.

- Food industry supply chains are dominated by SMEs, many of which may struggle to adopt advanced or costly interventions due to limited technical capacity or financial flexibility.
- The ability to shut down equipment for thorough cleaning is often constrained, exacerbating these risks.
- There is a risk that cost-cutting measures, particularly during scale-up, can push hygiene processes beyond safe limits or overlook biofilm risks entirely.
- Many food businesses, particularly larger operators, seek quick-impact solutions that deliver an immediate return on investment. This demand for rapid results can discourage the adoption of longer-term or more nuanced biofilm management strategies.
- Biofilms are rarely acknowledged within the food industry until a problem arises, typically through root-cause analysis following contamination or product failure, which leads to costly reactive interventions.
- Complex data (e.g. from metagenomics) often fails to translate into actionable interventions at company level.
- There is a disconnect between academic tools and industrial monitoring needs where laboratory models and media do not reflect real-world food processing environments.

PROPOSED SOLUTIONS

- Build a financial case for biofilm prevention and demonstrate return on investment.
- Propose open-access platforms to disseminate information on biofilms, prevention, and intervention strategies.
- Encourage mentorship and succession planning to retain microbiological expertise.
- Greater use of case studies, both positive and cautionary, to build sector awareness, ideally anonymised for industry acceptance.
- Opening dialogue between food producers and their customers can be an effective mechanism for raising expectations and accelerating best practice adoption.
- A coordinated framework which is needed to support biofilm management, involving:

□ Government support – policy, funding, and coordination.
□ Regulators, including HSE, ECHA, FSA, to align and clarify expectations.
□ Test providers to offer accredited and standardised testing capabilities.
□ Trade associations to facilitate industry engagement and promote uptake.
□ Education providers to deliver training, continuing professional development, and awareness at all workforce levels.
□ Manufacturers and designers to ensure hygienic design principles are integrated into equipment from the outset.
□ Foresight on future challenges, especially the risk of tolerance or resistance to current biocidal chemistries, which may undermine current control strategies.

- Shared learning and incident reporting would be beneficial. There is little visibility of contamination incidents across the sector and lessons are rarely generalised or shared. The below were suggested as potential solutions:

□ Establish anonymous, centralised failure databases similar to GMP+ (Dutch model) in animal feed/product industries.
□ Encourage trend analysis and early warning through data sharing, e.g. linking product rejections, contamination events, and inspection results.
□ Use AI and environmental data (climate, traffic, production schedules) to predict biofilm triggers.
□ Leverage existing rejection databases (e.g. FSA, ASDA) for pattern recognition and common source tracing.

- Lobby retailers and supermarkets, as their operations are predominantly driven by customer demands, to enforce high standards and demand demonstrable action on biofilm control.

Biofilm Detection, Monitoring, Prevention and Control in the Food Sector

CURRENT STATE

- A wide range of methods are used in the food industry to detect, monitor, and control biofilms, although none are yet standardised or universally applied. Common tools include visual inspection, swabbing, enzyme-based cleaning, and commercially available detection sprays.
- Detection tools such as Biofinder and FreshCheck are used to identify areas of concern. Once high-risk zones are detected, these sites are often treated with targeted enzyme or shock treatments, followed by post-treatment surveying. Hygiene performance is sometimes benchmarked against pathogen prevalence, e.g. aiming for less than 2% detection of *Listeria monocytogenes* in the food processing environment (FPE).
- Swabbing and surface testing remains the primary approach for monitoring microbial contamination. This includes:

□ ATP swabs, which detect residual organic material (not specific to biofilms). Placement of swabs is critical but not standardised, and validation is required to ensure appropriate surface targeting.
□ Protein swabs and colourimetric swabs, which detect proteins and microbial residues post-cleaning.
□ Standard microbiological swabbing, which indicates contamination via microbial growth but often fails to detect embedded or mature biofilms.

- Other biofilm detection methods include extracellular polymeric substance (EPS) detection using colour indicators or dyes. These offer a more direct indication of biofilm presence but may still require lab confirmation. Visual inspection is widely used but highly subjective and ineffective at detecting early-stage or transparent biofilms.
- Product testing, such as shelf-life studies, total bacterial counts (TBC), and total yeast and mould counts (TYMC), serves as an indirect indicator of hygiene issues, though not biofilm-specific. Air monitoring, using settle plates, also contributes to microbial quality assessment post-cleaning.
- Detection protocols and testing guidelines are highly variable across the industry, often differing between SMEs, retailers, and manufacturers. They are typically based on internal risk assessments or audit requirements rather than unified standards.
- In many cases, the discovery of a suspected biofilm triggers external consultation with academic institutions, testing laboratories, or support from e.g. Campden BRI. This may lead to more targeted testing, surface mapping, and validation of new methods.
- Some tools, such as reactive sprays, provide simple visual confirmation of biofilm presence, though they often lack quantifiability and specificity. Multistage cleaning interventions are also employed, e.g. glycolic acid followed by peracetic acid (PAA), enzymatic treatment, and steam application to delayer and remove biofilms, especially when traditional chemistries alone are insufficient.
- Cleaning strategies must be tailored to different surface types and systems, including inline pipes and air-exposed areas. Delivery methods vary and include liquid-based chemicals and enzymes, UV light, ozone gas, and biologics.
- A “fix-before-fail” approach to condition monitoring is encouraged to proactively resolve wear-and-tear, reducing hygiene risks. Cleaning and disinfection demand critical thinking, with real-time detection seen as key to enabling swift and targeted responses. A positive biofilm detection should always trigger a site- and product-specific intervention plan.

CHALLENGES AND BARRIERS

- Despite widespread use of swabbing, its effectiveness for biofilm detection remains questionable. There are concerns around: sensitivity, appropriate surface targeting, limits of detection, and consistency across sites.
- Visual sprays can detect biofilms but are not quantifiable and often lack sufficient specificity. The industry therefore requires reliable, easy-to-use, and quantifiable tools, ideally as simple as lateral-flow tests, which provide actionable results that directly inform validated disinfection strategies.
- Current testing methods, particularly those involving lab diagnostics, are often prohibitively expensive, creating barriers for small and mid-sized companies. Lab-based conditions also fail to replicate the complexity of real-world food processing environments. Understanding microbial ecology within facilities requires extensive sampling, operational discipline, and monitoring of previously untested sites.
- Results must be simplified and presented in accessible formats, such as colour-change indicators, usable by both technical and non-technical staff. However, there remains a lack of agreed biofilm parameters, defined indicator organisms, and sensitive detection technologies. Advanced diagnostics such as molecular tools are difficult to interpret for frontline staff and must be accompanied by actionable guidance.

PROPOSED SOLUTIONS

- To overcome these challenges, the food industry requires:

□ Simple, reliable, and quantifiable detection tools, ideally similar in ease of use to lateral-flow tests,
□ Actionable detection strategies, tightly linked to validated cleaning protocols,
□ Tools that enable real-time monitoring with minimal hardware and interpretive burden, such as bright colour indicators.

- Verification and monitoring must move beyond generic hygiene indicators. Validated methods should demonstrate clear impact on product safety, as evidenced by:

□ Fewer recalls,
□ Reduced customer complaints,
□ Decrease in reported illness.

- Where hygiene efforts fail to deliver measurable benefits, resources should be redirected. There is also a clear need for European (EN) standards that can be used to evaluate and benchmark biocide efficacy specifically against biofilms.
- Post-intervention monitoring should be standardised to track biofilm regrowth and evaluate residual risk. Interventions should be assessed for their potential to leave behind partially removed biofilms, which can reseed contamination.
- Emerging technologies that offer promise include:

□ Remote sensor-based, human-independent monitoring,
□ Molecular diagnostics for non-clinical species detection,
□ AI-enhanced tools to predict contamination risk.

- Finally, rotating cleaning and disinfection strategies may reduce resistance development and enhance long-term effectiveness, this area warrants further research and validation.

Conclusions

The discussions confirmed that biofilms represent a significant yet under-recognised threat to food safety across the sector. Although awareness is increasing, there remains a widespread lack of understanding, particularly where internal technical expertise is limited. Detection and monitoring approaches vary considerably, and current methods are frequently inadequate for identifying and quantifying biofilms in real-world conditions. Cleaning protocols are not always effective, especially against mature biofilms, and the absence of standardised guidance exacerbates the problem.

The existing regulatory framework does not explicitly address biofilms, leaving businesses to rely on internal procedures or retailer-led standards. With the UK's post-Brexit divergence from EU frameworks such as the General Food Law Regulation and European Food Safety Authority (EFSA) guidance, there is a clear opportunity to modernise food safety policy to better reflect contemporary pathogen risks. While no comprehensive regulatory overhaul has yet occurred, the Food Standards Agency (FSA) is reviewing safety frameworks, including testing requirements.

This regulatory inconsistency particularly hampers progress for smaller businesses. Nonetheless, there is an opportunity to bridge the gap between academic research and industry needs, enhance detection technologies, and embed food safety more deeply into organisational culture. Coordinated action is needed across stakeholders to develop practical standards, build workforce capability, and foster cross-sector learning.

The discussions identified several actionable steps that could be driven by the cooperating networks - Biofilm Alliance, NBIC, and FSRN, to support the food industry in building consensus and influencing future regulation. These include:

- Leading the development of sector-specific definitions and best practice guidelines for biofilm detection, intervention, and validation.
- Supporting the community in the creation and adoption of real-time, cost-effective, and user-friendly detection technologies for routine use.
- Drive the development and provision of simplified biofilm guidance, practical resources, and scalable tools as well as CPD-accredited training, mentorship programmes, and open-access educational content to enhance cross-sector understanding and capability.
- Explore the establishment of centralised platforms for incident reporting, shared learning, and case study dissemination to enable coordinated improvement across the sector.
- Engage with regulatory and trade bodies, such as the FSA, BRCGS, Campden BRI, and CFA, to align regulatory expectations and promote the adoption of harmonised, evidence-based biofilm control measures.

14

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