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Food fraud prevention strategies: Building an effective verification ecosystem

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Abstract

Food fraud is an ever-present threat that regulators, food business operators (FBOs), and consumers need to be aware of, prevent where possible, and address by developing mitigation strategies to detect and reduce its negative consequences. While extant literature focuses on food fraud detection, there is less attention given to prevention strategies, a knowledge gap this review seeks to address. The aim of this review was to consider food-related fraud prevention initiatives, understand what has worked well, and develop a series of recommendations on preventing food fraud, both policy related and for future research. Reactive (including intelligence based) food fraud detection dominates over prevention strategies, especially where financial, knowledge, and time resources are scarce. First-generation tools have been developed for food fraud vulnerability assessment, risk analysis, and development of food fraud prevention strategies. However, examples of integrated food control management systems at FBO, supply chain, and regulatory levels for prevention are limited. The lack of hybrid (public/private) integration of food fraud prevention strategies, as well as an effective verification ecosystem, weakens existing food fraud prevention plans. While there are several emergent practice models for food fraud prevention, they need to be strengthened to focus more specifically on capable guardians and target hardening. This work has implications for policymakers, Official Controls bodies, the food industry, and ultimately consumers who seek to consistently purchase food that is safe, legal, and authentic.

KEYWORDS
food fraud, prevention, prevention strategies, triangulation, verification ecosystem

1 | INTRODUCTION

Fraud is a complex and elusive concept in terms of its legal and also behavioral aspects (Reurink, 2018). Fraud is "any crime which uses deception as its principal modus operandi" (Wells, 1997) and thus embraces a wide range of deviant behaviors by individuals and organizations, some of which are not criminal in themselves, but can be described as "morally dubious" (Wells, 1997). According to Spink, Fortin et al. (2016), vulnerability and risk are the two main concepts that need to be considered when developing a food-related fraud prevention strategy, first in terms of the policy and process aspect, and then with regard to the methods and techniques for effective verification of the controls applied. Manning and Soon (2019) categorize vulnerability as intrinsic vulnerability, which occurs at the micro (the individual) and the meso (the food business operator [FBO]) level, or extrinsic vulnerability, which exists at the macro (the external environment, supply chain, or event, such as war or conflict, and harvest failure) level. Understanding where vulnerability can arise is key to ensuring timely prevention and detection of fraud (Lawrence et al., 2022). Vulnerability occurs due to a weakness or a flaw in a food control management system (FCMS), for example, weak validation processes, a sudden change in circumstances, a gap in existing management strategies, or if there is a failure of an element of the FCMS when it is operationalized, for example, weak verification processes (Manning & Soon, 2019; Soon, Krzyzaniak, et al., 2019; Zio, 2016). Irrespective of the scale at which it is operationalized, any weaknesses or flaws in the FCMS create opportunities and motivation for individuals and organizations to commit fraud (Spink et al., 2017; Van Ruth et al., 2017).

The Global Food Safety Initiative (GFSI, 2018) defines food fraud vulnerability, as "the susceptibility or exposure to a food fraud risk, which is regarded as a gap or deficiency that could place consumer health at risk, if not addressed." This definition links vulnerability as a weakness to risk either as a system weakness or as an outcome for food system stakeholders including consumers. These varying aspects of *food fraud vulnerability*, as an identifiable FCMS weakness, and *food fraud risk*, in terms of the likelihood and severity of exposure of different food system stakeholders to food-related fraud, are of interest in this research, serving first as a conceptual framework and second as a basis for assessing how both are evaluated in practice to inform effective food fraud prevention strategies. Food fraud vulnerability is currently assessed at an industry level through the use of a number of first-generation tools such as threat analysis critical control point (TACCP) (PAS 96, 2017; see also Zio, 2016), SSAFE (SSAFE, n.d.), or vulnerability analysis critical control point (VACCP) (GFSI, 2018), where VACCP more commonly focuses on wider aspects of food fraud. These tools will be evaluated and critiqued later in this review.

In summary, food-related fraud has emerged as a serious problem that may compromise the safety and quality of food products being sold (Marvin et al., 2022). Thus, the need for effective prevention strategies to safeguard the population from personal harm (food safety) and economic harm (quality and legality) is crucial. This fraud-related safeguarding needs to address both the identification and amelioration of weaknesses (actual and potential) in FCMS and also reduce the likelihood and severity of potential harm(s) if a fraud event is executed. Responsibility for prevention falls into two elements here—the role of the regulator and the role of the food industry. The regulator must set clear requirements with regard to the prevention of food fraud, and the food industry must effectively design, implement, and verify food fraud prevention, detection, and mitigation strategies at the business and supply chain level (Onarinde et al., 2023; Spink & Moyer, 2011; Wisniewski & Buschulte, 2019). In this context, *prevention strategies* are adopted to either stop or significantly reduce the likelihood that a fraudulent event occurs (Moyer et al., 2017; Spink et al., 2017; Spink, Bedard, et al., 2019; Spink, Chen, et al., 2019). There is a clear cognitive and operational distinction within both policy and practice between prevention strategies, designed to stop fraudulent activity from occurring, and *mitigation strategies*, that is, enacting further controls on the assumption that fraud is likely to have occurred and seeking to minimize the consequences (Spink et al., 2017; Spink, Chen, et al., 2019), and this differentiation forms a narrative theme in this review.

The aim of this review is to consider successful initiatives for fraud prevention, identify best practices within these initiatives and strategies to inform food fraud prevention, and develop a series of recommendations for policy and future research. Using a grounded foundational literature review and then a series of iterative searches, a theoretical framing of narrative themes has been developed within this paper that has been derived from the emerging evidence synthesis and analysis rather than through deductive forcing of preexisting theories or hypotheses. This approach to literature synthesis provides a more flexible and reflexive perspective to data saturation, data richness, and quality of critique compared to highly structured synthesis alternatives, and as a result—especially for nascent concepts and themes, such as food fraud prevention and the development of integrated guardianship networks and verification ecosystems—it delivers more holistic, system-level outcomes in terms of evidence assessment (Fusar Poli & Fontefrancesco, 2024).

The structure of the review is as follows: Section 1 introduces the review; Section 2 positions the types of food fraud and the approach to characterizing the situations where it occurs; Section 3 defines and critiques the development of FCMS to prevent food fraud; Section 4 builds on this by exploring how food fraud prevention strategies and food fraud prevention plans can be designed, developed, integrated, and verified as part of a wider FCMS at FBO, supply chain, and national regulatory levels (the concept of verification ecosystems is introduced); and finally, Section 5 concludes the review. The research evaluates the strengths and weaknesses of food fraud prevention and mitigation strategies and the application of existing food fraud vulnerability assessment (FFVA) tools. The research seeks to provide insight into the development, validation, implementation, and integration of food fraud prevention strategies and the operationalization of effective fraud-related verification ecosystems. The findings contribute to the further development of regulatory and market approaches to food fraud prevention.

2 | THE OCCURRENCE AND TYPES OF FOOD FRAUD

It is helpful to consider what distinguishes food fraud and food crime from the concept of consumer prejudice, which is an established legal concept most recently enacted in the United Kingdom by the Food Safety Act 1990. The legal attributes of mens rea (i.e., the guilty mind) and actus reus (i.e., acts or conduct that are a constituent element of a crime) tend to separate intentional food fraud and food-related crimes from FBO-related behaviors that are unintentional mistakes or errors, typically in formulations or labeling, where it is apposite to consider them on a spectrum of regulatory noncompliance and actor negligence.

2.1 | Types of food fraud

The UK National Food Crime Unit (NFCU, 2023a), a law enforcement capability within the Food Standards Agency (FSA), defines food crime as being "serious fraud and related criminality within food supply chains." Typologies of food fraud have been presented extensively in the academic literature (see GAO [2009], GFSI [2014], Manning & Soon [2014, 2016], Spink & Moyer [2011], and others for a wider discussion). Food chain-specific research has also developed a typology of fraud in specific food sectors such as seafood fraud (Fox et al. [2018], Lawrence et al. [2022], Lawrence, Elliott, et al. [2024], Lawrence, van Ruth, et al. [2024], among others). The NFCU characterizes seven aspects of food fraud within wider food crime offenses, which can occur individually or in combination in a given incident or pattern of offending (NFCU, 2023b). These are as follows:

1. Adulteration—including a foreign substance that is not on the product's label to lower costs or suggest that the food is of higher quality;
2. Document fraud—making, using, or possessing false documents with the intent to sell or market a fraudulent or substandard product;
3. Illegal processing—slaughtering or preparing meat and related products in unapproved premises or using unauthorized techniques;
4. Misrepresentation—marketing or labeling a product to wrongly infer its quality, safety, source, origin, or freshness, for example, selling a previously frozen product as fresh without declaring this on the label;
5. Substitution—replacing a food or ingredient with another substance that is similar but inferior, for example, substitution of olive oil with another plant oil;
6. Theft—dishonestly obtaining food, drink, or feed products to profit from their use or sale;
7. Waste diversion—illegally diverting food, drink, or feed meant for disposal back into the supply chain.

The UK FSA and the UK Department for Environment, Food and Rural Affairs (Defra) describe food fraud as the act of "deliberately placing food on the market for financial gain, with the intention of deceiving the consumer" (Defra, 2014). Food fraud has also been considered in the literature in a wider, more holistic organizational sense rather than a specific typology:

> "Food fraud is committed by any actor who is intentionally involved in illegal acts for economic advantage, thus causing or facilitating illegal food to be laundered into the supply chain or for food to be fraudulently value-enhanced" (Gussow, 2020, p. 113).

The need to demonstrate intention to determine activities as being fraudulent is clear here. The Global Food Safety Initiative (GFSI, 2018) differentiates between the prevention of unintentional contamination and the prevention of intentional adulteration of food products. Gussow (2020) addresses the focus of perpetrators on gaining economic advantage and value enhancement through the activity, or event, and also the consequences of fraud. Thus, this description focuses on both the nature of the activity and the person(s) undertaking the activity, that is, the nature of the offending behavior. Patterns of offending behavior are often used to create a typology of activities or

behaviors associated with criminal activity (Soothill et al., 2002). Manning et al. (2016) also developed a perpetrator-focused organizational typology for criminals targeting the meat supply chain. While PAS 96 (BSI, 2017), associated with TACCP, details a wider classification of food fraud and food defense-related criminals, it defines perpetrators through their activity and/or motivation: the extortionist, the extremist, the opportunist, the irrational individual, the disgruntled individual, the professional criminal, and the cybercriminal or malicious digital actor.

When considering who would commit food fraud, perpetrators can be characterized in terms of the criminal activities they undertake and their level of professional execution and complexity, for example, from one-off events to highly organized networks of criminal activity (Manning et al., 2016; Spink et al., 2013; Williams, 2001). Manning et al. (2016) in their typology focused on the ideological criminal, the professional criminal who only operates illicit activities, the recreational criminal who undertakes crime for entertainment or amusement, the occasional criminal who is an opportunist and undertakes low-frequency criminal activity, and the occupational criminal who undertakes their crime at their place of work in the legal economy. Occupational fraud is fraud committed by employees against the organizations that they work for, sometimes called insider fraud, internal fraud, or employee fraud (Suh et al., 2019) or fraud committed by the "bad apple" (Manning, 2024). Organized fraud can encompass both organized criminal gangs and also seemingly legitimate businesses that as corporate crime actors undertake recognizable crimes (Rizzuti, 2022), that is, the "bad barrel" where the organization behaves unethically and is motivated to commit fraud for economic gain (Gottschalk, 2013; Gottschalk et al., 2011; Manning, 2024).

Moyer et al. (2017) considered both macro supply chain-level and, more specifically, micro individual-level socioeconomic factors that impact the extent of the economic gain that could be derived and the characteristics of the location or business situation that make it more likely that criminal activity could occur. They argue that most food-related fraud is undertaken by occupational criminals, within otherwise seemingly legitimate food supply chains, and there are examples of this behavior described in this paper. This assertion positions food fraud as "situated actions" (Suchman, 1987), whereby situational action theory identifies an individual or group's propensity to commit the act and the criminogenic features of the setting as direct causes of crime (Kleinewiese, 2022).

Vaughan (1996, 1998, 2007) reflects on how the setting influences the crime and state, "fundamental sociological understanding is that interaction takes place in socially organized settings. Rather than isolating the action [event] from its circumstances, the task… is to uncover the relationship between the individual act and the social context." Thus, when considering how to embed strategies to prevent food fraud in given food supply chain situations, it is essential to examine and contextualize factors such as material and social settings and circumstances, and how in themselves they shape and inform criminal behavior (Onarinde et al., 2023). This paper draws together and integrates situational analysis and theories of situational crime prevention within the framing of food-related fraud. Considering food fraud as being "enterprise-related" allows for the development of context-specific situational prevention approaches that provide insight into contexts and structures that inform, drive, or "make rational" the decision processes of perpetrators to commit fraud (Onarinde et al., 2023).

2.2 | Situational prevention theory

Situational prevention theory considers the situated nature of crime and has informed much of the existing literature on food fraud prevention. The approaches and tools that have been previously proposed use the principles of routine activity theory to consider the range of opportunities and the circumstances surrounding a given crime (Cohen & Felson, 1979; Lord et al., 2017; Spink, Fortin et al., 2016; Spink, Chen, et al., 2019). The SSAFE tool, for example, is based on routine action theory (Lawrence, van Ruth, et al., 2024; Rezazade et al., 2022a). Situational crime prevention is described in terms of the "crime triangle," which is composed of three components: victim, fraudster, and guardian and hurdle gaps (Spink, Chen, et al., 2019). Rather than focusing on the causes, motivations, and propensities of individuals, situational prevention theory considers the practical mechanisms for reducing opportunities for criminal activity and, where this is not possible, minimizing the impact. This outcome is achieved by considering the interplay between opportunities, motivations, and countermeasures associated with a food fraud event (Rezazade et al., 2022a). Rezazade et al. (2022b, p. 4123) explain that "routine activity theory principles show that food fraud occurs when there are low levels of control (countermeasures) applied to the area of vulnerability (or food fraud vulnerability factors) by victims of food fraud (e.g. food companies)." The vulnerability factors they cite include length and complexity of the food supply chain, economic shocks such as "price spikes," and weak traceability systems and loss of transparency, which is described later in this paper as "chains of custody."

2.3 | Countermeasures

Countermeasures are security measures operationalized to reduce the likelihood of criminal opportunity in individual food businesses or within food supply chains (Spink et al., 2015). Effective countermeasures reduce the capability and opportunity for fraud, and if enacted, they can limit the impact (Mitenius et al., 2014). Countermeasures can be preventive, detective, or corrective (Bendovschi, 2015). Lord et al. (2017) argue that control measures or countermeasures fall into five categories:

1. Increasing the effort needed to commit the fraud through the use of hurdles and reducing opportunity (opportunity), for example, by adopting security protocols such as visitor access procedures or designing out opportunities for unauthorized access to premises, creating secure entry facilities to critical areas of the factory and storage areas.
2. Increasing the risk of fraud being detected by guardians (detection), for example, by increasing surveillance of the business environment, implementing security audits, documentation audits, and product audits, and installing closed circuit television (CCTV).
3. Reducing the rewards associated with committing the fraud (incentive), through confiscating profits gained or custodial sentences associated with committing food fraud or being delisted as a supplier.
4. Reducing the temptation to commit fraud (motivation) by reducing the temptation for suppliers to commit fraud as a result of contract agreements or pricing strategies that mean the supplier is financially compromised, thereby alleviating organizational and market pressures. Ensuring that staff are paid appropriately and that any actions are not driven by economic necessity.
5. Removing the excuses (rationalization) by introducing controls, protocols, and training to prevent fraud. Ensuring that fraud prevention strategies are suitably communicated at organizational and supply chain levels.

Target hardening as a concept has been highlighted in the food fraud literature as a means to better manage the potential for food fraud and reduce vulnerability (Cadieux et al., 2019; Onarinde et al., 2023; Spink, 2021; Spink, Chen, et al., 2019). Target hardening means any activity, action, intervention, or technique that makes food fraud more difficult to achieve and/or more likely to be detected. Target hardening protocols are increasingly being adopted to address financial fraud, for example, two-step verification of banking apps, and ransomware attacks, for example, virus software, firewalls, and cyber defense protocols (Manning & Kowalska, 2023); therefore, developing target hardening protocols must be a key element of a food fraud prevention plan. Guardians and hurdles are now considered in more detail.

2.4 | Guardians

2.4.1 | Capable guardianship

A capable guardian is any actor, individual, or intervention that discourages crime from taking place (Cohen & Felson, 1979), by being "present" (Felson, 1995; Reynald, 2009) or through being active or passive in their role (Reynald, 2009). A capable guardian "can serve as a key actor in the crime event model; one who can disrupt, either directly or indirectly, the interaction between a motivated offender and a suitable target" (Hollis-Peel et al., 2011, p. 53). Guardians, in the context of food fraud, undertake a range of activities including validation, monitoring, and verification in order to protect food, consumers, and the food industry from economic, personal, and business harm (Cohen & Felson, 1979). Effective guardianship requires both shared leadership and multi-actor collaboration to develop and integrate a public–private interorganizational guardianship network involving regulators and enforcement bodies, multinational organizations, and smaller FBOs to overcome vulnerabilities associated with limited knowledge, information, and safeguarding capacity (Kowalska & Manning, 2022; Qian et al., 2020). Examples of safeguarding capacity include the coordinated design and implementation of food fraud preventive measures, as well as monitoring and surveillance systems.

Capable guardianship is a well-researched concept in the criminology literature (Hollis-Peel & Welsh [2014], Hollis-Peel et al. [2011, 2013], Leclerc & Reynald [2017], Reynald [2009, 2010, 2011], Ylang [2020], among others). Multilevel prevention strategies for financial fraud in Australia (Lindley et al., 2011) and the wider banking sector highlight computer-based/telephone app two-step verification technology within a wider verification ecosystem (individual, business [e.g., bank], regulator). This concept of self-guardianship, where responsibility lies with the individual to take the appropriate preventive measures themselves, prevents them from becoming a victim of fraud (Onarinde et al., 2023). The concept of self-guardianship as a victim-focused preventative approach has also been considered in terms of cyber abuse (Vakhitova et al., 2023); identity theft (Choi et al., 2022); and theft (Marteache & Trinidad, 2024). Capable guardianship combines both personal self-guardianship (protecting oneself from fraud through a number of safeguards an individual can adopt) and also physical guardianship,

in terms of the technological hurdles embedded within software systems to prevent fraudulent activity from occurring (Ylang, 2020). Consumers, for example, can become more capable self-guardians through the implementation of focused education and awareness programs, whereby, when informed, they can demand that certain countermeasures are in place to reduce their risk of being defrauded (Lawrence, van Ruth, et al., 2024).

Ellis et al. (2016, p. 11), in the context of food fraud, suggest technological solutions can be part of a capable guardianship system and argue that "future sensor/detection platforms and technologies, along with future predictive computational methods could together take on the capable guardian role and assist in significantly reducing the areas of vulnerability to fraud within food supply chains." With the advent of artificial intelligence, deep learning, and algorithmically powered predictive analytical techniques, guardians can use these technologies to adopt a proactive approach to predicting the factors that can lead to fraud so they can then implement appropriate preventive countermeasures before the event can be realized (Demeshko et al., 2024; Gupta, 2024). Federated learning has been suggested as one predictive approach that is of value with regard to food fraud (Gavai et al., 2023).

2.4.2 | Integrated guardianship networks

Public authorities are only one source of food fraud guardianship. A more sustainable preventive approach is to strengthen surveillance by multiple actors (guardians) across the food supply chain within an integrated guardianship network. Within the network, there can be formal guardians who exercise their guardianship role in an official capacity, for example, in the United Kingdom, the NFCU, and informal guardians such as FBOs or consumers (van Sintemaartensdijk et al., 2024). One example of an integrated guardianship network is the UK's Food Industry Intelligence Network (FIIN) (https://www.fiin.co.uk), which has over 60 members including primary producers, manufacturers and processors, food service organizations, and food retailers who have come together to improve integrity in food supply chains. Another example is the Food Authenticity Network (FAN) (https://www.foodauthenticity.global/FAN), which operationalizes on a global scale an integrated guardianship network. One important way to ensure capable guardianship is in place is to promote awareness of food fraud and ensure that FBOs know what food fraud is, how to spot suspicious activity, and what to do to stop it and report it (Onarinde et al., 2023). van Sintemaartensdijk et al. (2024) position that symbolic guardianship is also important as a deterrent, a key aspect of prevention, including the use of signs, CCTV and surveillance cameras, and the visual presence of human guardians. Others include invisible guardianship, for example, the use of forensic traceable liquid on historical artifacts as deterrents (Koush, 2024) and visible capable guardian artifacts that can be inspected and audited (Manning, 2024).

2.5 | Hurdles

Hurdles (countermeasures) that are implemented by individual guardians and/or through a capable guardianship network (van Ruth et al., 2017) will reduce the likelihood of fraud. Appropriate hurdles can be identified during the development and adoption of food fraud prevention strategies and food fraud prevention plans and are components of FCMSs that reduce fraud opportunities by improving detection or acting as a deterrence, for example, security controls for entry to factories or storage areas (Spink & Moyer, 2011; Spink et al., 2015). Thus, deterrence-based hurdles are also elements of symbolic capable guardianship. Hurdles can be physical, hard, or active measures to protect structural assets (access protocols, enclosed production lines, and processing systems) or soft, artifact-based, passive measures including protocols, procedures, and practices designed to reduce the likelihood of a fraud event (Manning, 2019, 2023; Mitenus et al., 2014; van Ruth et al., 2017). Hurdles can be on-line (production line), such as in-line testing or anticounterfeiting measures embedded in packaging; off-line, for example, laboratory tests or documentation checks (Soon & Manning, 2019); or reactive, for example, whistleblowing protocols (Cane & Primrose, 2021; Suh & Shim, 2020). Spink et al. (2015) describe hurdle gaps as the vulnerability that arises when there are no effective hurdles in place, or where they have been developed and implemented but are ineffective. The next section considers FCMS, involving a dual process of triangulating both the effectiveness of the FCMS itself and the evidence of its implementation, as well as the development of verification ecosystems.

3 | FCMS, EVIDENCE TRIANGULATION, AND VERIFICATION ECOSYSTEMS

3.1 | Food control management system

Food control management defines the responsibilities and interrelated cooperation between central government, local government, and FBOs to ensure food is safe and meets legal requirements (Jia & Jukes, 2013). The scope of a

national FCMS includes the establishment and enabling of regulatory instruments and associated policy guidance and the monitoring of the performance of the FCMS in practice in order to facilitate continuous improvement (Ahmad et al., 2018; FAO & WHO, 2003). At the FBO level, FCMS refers to "the overall control of the FBO's processes i.e., encompassing food safety, nature, substance and quality, food authenticity and food integrity, compliance with statutory compositional standards, traceability, food fraud, food defense and management activities including validation, monitoring, and verification" (Onarinde et al., 2023, p. 8). An effective and resilient national FCMS requires the integration of FCMS driven by the national regulator and also by FBO-driven FCMS through a capable guardianship network rather than seeking to develop resistance capacity focused solely on compliance (Mu et al., 2021). This means that "appropriateness" of an FCMS is not a static concept but instead is agile, sometimes reactive, and adaptive.

3.1.1 | Verification

Vulnerability in the context of food fraud prevention has been positioned as different from risk. Risk is the potential for an unwanted outcome resulting from an incident, event, or occurrence, as determined by its likelihood and the associated consequences should it occur (Spink, 2019; Spink, Chen, et al., 2019). Once fraud vulnerabilities are identified and, if possible, quantified, this can then inform the development of food fraud prevention and mitigation programs contained within FCMSs. Effective and repeated verification of FCMSs is an important element of food fraud prevention. Verification activities are most frequently associated with auditing to determine the level of organizational compliance with regulatory requirements, third-party certification, or other market standards (Manning, 2018; Manning & Monaghan, 2019). Auditing is a tool that can be used to monitor the level of compliance and, through the assessment of objective evidence, provide transparency that FCMSs are effectively developed, adopted, and implemented (Onarinde et al., 2023). Many private certification schemes advocate unannounced audits as a verification intervention of value (Elliott Review, 2014; Zhang et al., 2019).

In the United Kingdom, the Elliott (2014, p. 84) review, which considered the integrity and assurance of food supply networks, subsequent to the 2013 European horsemeat incident, argued that food integrity went beyond the nature, substance, quality, and safety of food, to include "the way it [food] has been sourced, procured, and distributed and being honest about those areas to consumers." However, a range of uncoordinated first-party (internal audits), second-party (customer audits of suppliers), and third-party audits (audits against private standards by independent bodies) and Official Controls verification (OCV) (Statutory State operated verification, e.g., in Europe by competent authorities, border controls, and local authorities) failed to prevent the 2013 horsemeat incident in Europe. Indeed, extant independent public and private verification activities were insufficient to prevent food fraud where the focus for verification was primarily on audits. Indeed, previous research at both state and federal levels in the United States failed to demonstrate that foodborne illness outbreaks were reduced through regulatory or market-based inspections and audits (Cruz et al., 2001; Irwin et al., 1989; Petran et al., 2012), nor were the audits frequent enough to verify food safety controls effectively (Kaplan, 1978). In the case of food fraud, illegal activities are unlikely to be perpetrated during an inspection or audit (Onarinde et al., 2023), indeed a mendacious organization may have openly "developed visible capable guardianship artefacts which can be inspected and audited whilst at the same time.. [are] intentionally facilitating covert misconduct" (Manning, 2024, p. 5). Therefore, auditing alone as a preventive hurdle, or an element within a capable guardianship network, is insufficient in itself as a verification activity to prevent fraud.

Reflections on the value and efficacy of auditing in fraud prevention have been raised in the banking sector (Dai & Handley-Schachier, 2015), with concerns that auditors were positively biased in their approach and looking for evidence of compliance, rather than actively seeking evidence of fraudulent behavior (Chong, 2013). Onarinde et al. (2023, p. 8) state that despite the level of resources (cost and time) that has gone into the inspection and auditing of FBOs, these traditional and transactional processes alone are not "sufficient to prevent fraud." Active fraud risk assessment and fraud risk management processes require routine intelligence gathering and sharing of intelligence between partners as key aspects of fraud prevention (Brooks et al., 2017; Butler et al., 2021). However, using single sources of evidence during verification activities increases the potential for being misled or "taken-in" by a single fraudulent document. Instead, Onarinde et al. (2023) argue that there needs to be both a verification challenge to the FCMS itself and a greater triangulation of evidence from a range of sources.

3.1.2 | Triangulation

Verification must be based on objective evidence. ISO 19011:2018 (ISO, 2018) defines objective evidence as verifiable evidence that can be obtained by any means, including observation, measurement, and testing, and consists of

information including records and statements of facts. The triangulation of evidence is most frequently understood to be verification from multiple sources, which avoids relying on single-source evidence that may in itself be unrepresentative, misleading, or fraudulent. Triangulation of evidence supports a greater understanding of an organization, its internal management structures and processes, and its performance (Bell et al., 2005). Triangulation counterbalances the strengths and weaknesses of different types of evidence and various data collection methodologies and approaches in verification, and as a result, it increases the consistency of processes, generalizability, and credibility of audit findings (Bauwens, 2010; Carugi, 2016; De Boeck et al., 2019; Jespersen & Wallace, 2017; Kopinak, 1999; Manning, 2018; Yeasmin & Rahman, 2012; Zanin et al., 2021). Triangulation has been proposed as a verification method for assessing risk (Bell et al., 2005), evaluating food fraud vulnerability (Alrobaish, Jacxsens, Spagnoli, et al., 2022), and examining an FCMS that has been developed to prevent fraud in what are often complicated, multilayered, and multidimensional situations (Kleboth et al., 2016; Onarinde et al., 2023), where evidence for fraud risk assessments (Trotman & Wright, 2012) can be qualitative, quantitative, direct, or circumstantial (Lokanan, 2019).

Triangulation of intelligence is an approach used in general crime investigations (Shea, 2022; Young, 2005). In terms of food fraud, Gussow and Mariët (2022) highlight the importance of triangulating information (intelligence) about the context and details of the fraud and the offender. Food safety culture and food safety climate have been considered together with triangulation methods in terms of how culture and climate frame food safety management systems (see De Boeck et al., 2015; 2016; 2018). This concept has been extended to include food fraud prevention and the association with food integrity culture and food integrity climate (FIC) in recent research (Alrobaish et al., 2021, 2023; Alrobaish, Jacxsens, Spagnoli, et al., 2022; Alrobaish, Jacxsens, & Vlerick, 2022). Alrobaish, Jacxsens, Spagnoli, et al. (2022) combined three tools in their proposed method of triangulation: (1) using the FIC self-assessment tool (human aspects), which determines employees' perceptions of an organization's FIC; (2) using key performance indicators within an interview to verify employees' perceptions with on-site observation (operational aspects); and (3) applying an FFVA diagnostic tool, such as SSAFE. SSAFE as a diagnostic tool has been proposed and applied within the food literature (van Ruth & de Pagter-de Witte, 2020; van Ruth et al., 2017).

As an example, verification, and in particular the triangulation of objective evidence, has been the focus of the approach developed by Food Standards Scotland (FSS). In 2022, OCV was published as an approach in relation to statutory regulatory verification as it is being applied in Scotland to FBOs approved under Regulation (EC) 853/2004. One of the key features of the OCV that distinguish it from traditional forms of regulatory inspecting and auditing is the explicit application of scientific rigor to its implementation and a dual process of triangulation. The FBO's FCMS is never accepted "as is," rather it is challenged in terms of its efficacy in context. Following that process, the implementation of the FCMS is verified, according to a process of triangulation of evidence wherein cross-referencing of different sources of evidence occurs, with the goal being corroboration and the enhancement of the degree of certainty about the inferences made, thereby avoiding reliance upon a single source of evidence (FSS, 2022). OCV, as stated above, incorporates such evidential triangulation as aforementioned but precedes it by an additional triangulation process involving the FBO's FCMS, the OCV study, and the consideration of the implementation of the FBO's FCMS in reality. This approach challenges the efficacy of the FCMS itself in order to avoid the potential pitfall of verifying the implementation of an FCMS that was not designed to be effective in the first place (FSS, 2022). OCV demonstrates promise in improving the effectiveness of existing approaches to regulatory verification (FSS, n.d.b). OCV is "a radical departure from conventional auditing as OCV places emphasis on the effectiveness and appropriateness of the FCMS (validation) and explicitly applies scientific methodology in verification by cross-referencing multiple corroborating sources of objective evidence" (Onarinde et al., 2023).

3.2 | Verification ecosystem

A verification ecosystem has been defined as "the network of interlocking methods and techniques for verification of FCMS in relation to food fraud," encompassing both the activities of FBO and state actors (Onarinde et al., 2023, p. 30). This definition builds upon and paraphrases the definition of a digital ecosystem proposed by Boley and Chang (2007), as well as a Blockchain-enabled digital ecosystem (Garg, 2021; Vashistha et al., 2021). The digitization of supply chain systems using Blockchain technology together with Internet of Things (IoT) applications, fraud detection technologies, and/or artificial intelligence to assure transparency and traceability and prevent food fraud has been proposed by a number of sources (Alkhudary et al., 2022; Bager et al., 2022; Chen et al., 2022; Danese et al., 2021; Hassoun et al. 2024; Lindley, 2022; Saha et al., 2024). However, to date, it has mainly been adopted by large organizations, and the opportunities for micro and small businesses still need to be determined (Jellason et al., 2024). Sources and characteristics of ecosystem data include a range of singular, multivariate, hierarchical, relational, temporal,

or spatial data, information, or artifacts within a specific context (Basole et al., 2015). Verification ecosystem data relating to the validation and efficacy in practice of an FCMS at organizational, supply chain, and national levels include product certification, auditing of objective evidence with triangulation of direct (from the application of the FCMS, e.g., quality assurance and quality control documentation) and indirect evidence sources (e.g., financial data such as purchase orders, invoices, and supplier information), and laboratory-based product authentication. Indeed, a number of industries have embedded what they describe as validation and verification or V&V strategies more generally within organizations and in the context of assuring suppliers (Shankar et al., 2017).

A verification ecosystem extends beyond normative, traditional, centralized, and compliance-based methods that can be used to assess organizational performance. Instead, a verification ecosystem is co-created through multi-evidence collaborative, hybrid, distributed, and transparent verification and surveillance processes for food environments that consistently deliver safe and legal food of the specified quality (Onarinde et al., 2023). A suitable verification ecosystem could provide evidence that an associated food fraud prevention strategy and a food fraud prevention plan are appropriate, robust, and effective when operationalized. A verification ecosystem recognizes that multiple systems interact with and within food systems. Manning (2024, p. 7) states that food fraud assessment tools need to:

> "improve understanding of the interaction between the individual, the organisation (FBO), the supply chain, the food system, the natural system, financial system and political system to better contextualise systemic food fraud and the environment in which it occurs."

The next section of the paper considers how food fraud prevention strategies and food fraud prevention plans can be designed, developed, integrated, and verified as part of a wider FCMS supported by an effective verification ecosystem.

4 | FOOD FRAUD PREVENTION STRATEGIES

Food fraud prevention is essential for protecting consumers from harm as well as enabling fair trading practices (Joenperä et al., 2022). Fraud prevention stops fraud from occurring, while detection informs measures to mitigate its effects or consequences when it occurs (Rodrigues et al., 2022), that is, after the event. The challenge with developing prevention strategies is that fraudsters adapt quickly to any interventions, making such strategies ineffective over time (Moreira et al., 2022). Thus, prevention strategies need to be agile and responsive to changing situations and drivers. Crime prevention—and in the context of this study, food fraud prevention—"entails any action designed to reduce the actual level of crime and/or the perceived fear of crime" (Lab, 2004, p. 682). The need for food fraud prevention strategies has been identified in both policy documents and academic literature. These strategies include many of the aspects outlined in this paper such as collaborative integrated capable guardianship networks that share information and undertake horizon scanning, regulatory processes for horizon scanning and intelligence analysis, and the use of predictive data analytics (Gavai et al., 2023).

4.1 | Private food standards' approaches to food fraud prevention

Food fraud prevention is a focus of private food standards such as those aligned with the Global Food Safety Initiative (GFSI, 2017; Spink, 2019). Since January 2018, the Global Food Safety Initiative has embedded requirements for a food fraud prevention strategy and an FFVA, where the FFVA informs the depth and scope of the food fraud prevention strategy that can be managed by the food fraud prevention cycle (FFPC) (Spink, Chen, et al., 2019). The UK Food and Drink Federation (FDF) also introduced guidance on addressing food fraud (FDF, 2014). Developing food fraud prevention strategies requires a process where there is an assessment of the opportunities and motivational drivers that increase vulnerability to fraud and then consideration of the preventive measures as well as the mitigation measures that eliminate, balance, and/or reduce vulnerability (van Ruth & Pagter de Witte, 2020). Song et al. (2021) differentiate between vulnerability prevention and risk mitigation, stating that food fraud mitigation strategies are based on subjective industry judgments and simple formulae, often using matrices as a tool, with associated limitations. However, the use of risk mitigation assessment tools such as SSAFE has raised awareness of food fraud as an industry issue (Silvis et al., 2017). The application of the SSAFE tool to the activities of the FBO and also upstream and downstream in their supply chain, as applicable, requires a depth of knowledge, understanding, and insight within the FBO team.

4.2 | Regulatory approaches to food fraud prevention

While, on the one hand, for market access, FBOs need to demonstrate compliance with GFSI-benchmarked standards, and have completed an FFVA and developed a food fraud prevention strategy, on the other hand for other FBOs, especially micro and small businesses, they may have no formal food fraud prevention strategy at all. The UK FSA has sought to develop FBO awareness and capability through its online food fraud resilience self-assessment tool (FSA, n.d.). FSS (n.d.a) has developed a food crime risk profiling tool to develop FBO awareness. The US FSMA Final Rule on Foreign Supplier Verification Programs for Importers of Food for Humans and Animals (FDA, 2023) requires FBO importers to perform risk-based foreign supplier verification activities to verify that the food concerned is both safe and not misbranded or adulterated. While larger manufacturing organizations, where it is a prerequisite to supply, have undertaken FFVAs, many micro and small FBOs have yet to adopt prevention strategies, and there is a lack of comprehensive food fraud prevention strategies at supply chain and food system levels. This is due in part to perceptions of how expensive such strategies are to implement in low-margin business sectors, when they may never be needed, and also a lack of surety of their level of effectiveness to actually stop an incident from occurring (Onarinde et al., 2023). More widely, such comprehensive prevention measures will only be effective and consumer trust improved when, first, food fraud and food crime definitions are better harmonized at a regulatory level and there is greater convergence of private and public approaches to food crime and food fraud classification; and second, governance and verification ecosystems need to be more effective and efficient (Manning & Kowalska, 2021; Onarinde et al., 2023), especially through the establishment of integrated capable guardianship networks and verification ecosystems.

4.3 | Food fraud prevention strategies focused on supplier verification

Guidance for food fraud prevention and mitigation has been produced by a number of organizations. Nestlé has produced guidance on food fraud prevention, especially within wider procurement and supplier verification strategies, and the requirement for vulnerability assessment to inform mitigation strategies (Nestlé, 2016). FBO-initiated supplier verification is described in the Elliot (2014) review as upstream prevention (Barrere et al., 2020; Guntzburger et al., 2020; Robson et al., 2021). Upstream prevention is not a new term, having been considered in terms of nutrition (Dorfman & Wallack, 2007), health and preventive medicine (McMahon, 2022; Wyman, 2014), and fraud (DuHadway et al., 2022; Grieco, 2021). Upstream thinking reflects prevention by ensuring that environments "support and even foster" appropriate decision-making (Dorfman & Wallack, 2007). Upstream prevention also has a spatial dynamic in terms of the loci of the fraud prevention strategy, being upstream, midstream, or downstream (Grieco, 2021), or upstream or downstream from a given point or transaction activity in a supply chain (DuHadway et al., 2022). The application of food fraud countermeasures, both upstream and downstream from a given supply chain step, must create visibility, be comprehensive, and provide integrated solutions (Onarinde et al., 2023). In the context of food fraud prevention, Barrere et al. (2020, p. 134) argue:

> "However, it remains unclear to what extent upstream suppliers may be held responsible for downstream fraud acts, and to what extent upstream suppliers have the ability to mitigate against fraud that occurs downstream of their direct control. It would be challenging for one entity to fully control the fraud risks in both the upstream and downstream supply chain."

Upstream prevention as part of an effective supply chain assurance program is a key strategic focus within strategic food fraud prevention (Onarinde et al., 2023). Regulatory pluralism whereby regulatory controls are implemented by multiple actors in a form of "regulatory partnership" has been proposed in complex crime contexts through engaging private and public actors (Lindley, 2018; 2019; 2022). Verification activities within a wider verification ecosystem as previously described can extend beyond FCMS-related information to include financial and other information too. While there is a clear focus in upstream prevention on effective traceability systems, the chain of custody (CoC) system builds upon traceability processes to include triangulation of objective evidence and verification including mass balance assessment, due diligence checks, and implementation of fraud detection activities (see Table 1).

Undertaking mass balance assessment as a verification activity is already a requirement in many third-party certification standards, but the development of digital "real-time" mass balance analysis within, and between, organizations would increase transparency and identify potential anomalies in the data collated. However, there is still the risk of fraudsters intentionally inputting fraudulent data. Again, triangulation of multiple sources of evidence rather than using evidence from a single source is

TABLE 1 Elements of a chain of custody system (adapted from the ISEAL Alliance, 2016; Onarinde et al., 2023).

Element	Rationale
Identification of origin and identity of materials	If claims are made regarding the composition and origin of a product, this can be tracked and traced from individual components to the final product through mass balance assessment and in reverse.
Identification of volume sold versus the materials stated as being used	Mass balance assessment demonstrates that the volume sold (production output) matches or does not exceed the volume expected to be produced from the materials used. Overproduction, sometimes called overrun, needs to be identified as equally as a loss of material, which could then be used for fraudulent purposes. Overproduction could be caused by dilution using inferior products or labeling of products that are not what they are claimed to be.
Immutable records that are linked to a lot or identifiable batch	Developing a secure, immutable record of the custodial sequence of all components of a final product from supplier through to consumer (this includes not only ingredients, but also packaging, processing aids, etc.)
Intelligence sharing	Developing communication between members of the supply chain, so intelligence can be shared
Procurement procedures	Developing procurement procedures with pre-supply and post-supply due diligence checks
Verification procedures	Verification of chain of custody, through testing, auditing, and other methods as appropriate

an important preventive measure to reduce the likelihood of a single instance or endemic fraudulent activity.

4.4 | Food fraud prevention strategies focused on FBO self-assessment

Some researchers report that VACCP and Enterprise Risk Management (ERM) approaches help to focus food fraud prevention strategies on specific situations, contexts, and the drivers of the decisions made by fraudsters to ensure the strategies are agile, relevant, rigorous, robust, responsive, and real-time (Barnard & O'Connor, 2017; Moyer et al., 2017). The use of SSAFE by FBOs has also been previously described. Applying the principles of VACCP at the FBO level to address wider food fraud issues provides a systematic approach to assessing food fraud risk and developing a management program through the evaluation of threats, identification, and prioritization of vulnerabilities, and then the implementation of appropriate controls to reduce vulnerability and the likelihood of a fraud incident occurring. These controls could be applied to the physical premises, materials, processing aids and products, procurement and purchasing protocols, processes, and business systems within the FBO and with other organizations such as contract manufacturers and distribution networks. Essentially the principles of VACCP need to be applied by a capable team with the resources and responsibility to effect the changes needed to procedures, processes, and the FCMS. When developing a food defense strategy, applying TACCP, which can be implemented using the PAS 96 guidelines (BSI, 2017), can not only support FBOs in characterizing and controlling intentional contamination but also determine potential perpetrators (Manning, 2019, 2023). Ahmed and Al-Mahmood (2023) suggest that the benefits to an FBO of implementing TACCP are reducing the likelihood of an intentional contamination through implementing reasonable precautions, protecting the FBO's reputation, reducing the consequences and impact if it occurs, and reassuring customers and consumers that the FBO is managing risk in the supply chain appropriately, demonstrating due diligence.

There is limited guidance regarding fraud prevention to enable the majority of micro and small enterprises that operate outside of major retail and food service supply chains where GFSI compliance is required. One option for micro and small enterprises that do not want to have separate hazard analysis critical control point (HACCP) (for food safety) and TACCP plans is to develop hazard analysis critical control point food defense plans (HACCP-DP). In an HACCP-DP approach, aspects of food safety, food fraud, and food defense are combined in a single assessment that uses the seven principles/12 steps of HACCP as a baseline with an additional food defense element (Davidson et al., 2017; Esteki et al., 2019; Manning, 2019; Wiśniewska, 2015). The three additional steps are (1) determination of critical defense points, (2) development of the food defense mitigation and control system, and (3) validation, implementation, assessment, maintenance, and verification of defense mitigation activities (Manning, 2019; Wiśniewska, 2015). These activities may be both preventive and detective countermeasures. This is worthy of future research.

4.5 | Food fraud prevention—Regulator-based strategies

4.5.1 | New Zealand and Australia

The cooperative Food Treaty between New Zealand and Australia in 2019 led to the harmonization of food

safety regulation between the two countries aligning with the subsequent Australia-New Zealand Food Standards Code (Lindley, 2022). Food fraud in Australia is regulated at both the state and federal levels, but some have argued for a more strategic, proactive, and holistic approach (Curll et al., 2016; Lindley, 2022). The United Nations Guidelines for Consumer Protection (UN Trade and Development, 2016) has also initiated a set of international consumer law principles together with a framework (Benöhr, 2020) applicable to developing national food fraud prevention plans. These outline that, through providing appropriate policy and guidance, governments should encourage FBOs to voluntarily adopt practices to protect consumers by avoiding food fraud. Three further guidelines are as follows: Guideline 83, which states that enforcement agencies must be given the resources and responsibilities to investigate fraud through better aligning investigation and enforcement activities across Member States; Guideline 85, which mandates enabling and extending existing international networks and arrangements; and Guideline 88, which calls for investigating, obtaining, and sharing intelligence, evidence, and information with other enforcement agencies.

4.5.2 | The United States

The US National Security Memorandum on Strengthening the Security and Resilience of US Food and Agriculture (FDA, 2023) links food security with essential national infrastructure. This security linkage has been proposed by a number of nation-states whereby food security (availability and safety) forms a key element of national security. At the Secretary of State and Agency level, an assessment of relevant food security and resilience risks, along with the undertaking of threat and vulnerability assessments and prioritization of risks for the agri-food industry, is mandated. The resultant assessments and supply continuity plans must be formally reviewed in the event of emergent, credible, and actionable threats or events. A strategy and action plan, combined with the identification of capabilities and a cost/benefit plan, must then be submitted to the President.

An additional piece of legislation, the US FSMA Final Rule on Foreign Supplier Verification Programs (FSVP) for Importers of Food for Humans and Animals (FDA, 2016), which addresses food safety and food fraud, must also be complied with. For foreign suppliers, the FSVP requires FBO importers to undertake risk-based verification activities to verify that the food is not adulterated or misbranded.

4.5.3 | Joint Nordic Threat Assessment for Food Fraud

After the aforementioned horsemeat incident in Europe, the Joint Nordic Threat Assessment for Food Fraud was launched by Norway, Denmark, and Sweden (Bar-Yaacov et al., 2022). In 2018, these countries evaluated potential food fraud-related threats that then informed national-level threat assessments a year later. These national-level threat assessments considered: raw materials of animal origin (with particular emphasis on tax and customs evasion, smuggling, theft, substitution, and unlawful production and processes); fish and seafood; declaration of Nordic origin; and declaration of organic production. The threat assessment used a matrix approach to prioritize potential threats based on four criteria (opportunities, motivation, supervisory measures, and impact), aligning with the SSAFE methodology with four additional criteria—two financial parameters (reputational loss and financial loss) and two social parameters (food safety and consumer confidence in process). The approach uses a scoring mechanism with four elements (high, moderate, low, and unknown), recognizing the reality of knowledge gaps making this methodology stand out from other threat and vulnerability assessments that are only based on knowable threats (Onarinde et al., 2023). There is always the potential for a "black swan" event, and this needs to be reflected when undertaking such assessments (Manning et al., 2020).

4.5.4 | The UK context for food fraud prevention

In the United Kingdom, Regulation (4) 3 of the Food Safety (General Food Hygiene) Regulations 1995 codified into UK law the FBO requirements to identify, control, and manage food hazards and was extended in 2006 by Regulation (EC) 852/2004. Building on the Food Safety Act 1990, this regulation "provides a statutory driver for Local Authorities to engage with inspections what became known as Official Controls placing great emphasis on Regulation 4 (3) i.e., verifying the measures for the prevention of foodborne illness" (Onarinde et al., 2023, p. 11). To support compliance with this legislation, especially the mandatory requirement for adoption of HACCP postharvest and post-slaughter, educational programs and FBO-focused guidance were developed. This approach has been highly transformative for the food sector, as compliance data demonstrate; however, this regulatory approach including its incentives and sanctions has not been extended to considerations of preventing food fraud.

A theme that has characterized the verification of FCMSs at state, FBO, and third-party levels is a lack of attention paid to the efficacy of verification activities. Traditional inspecting and auditing were shown to be inadequate during horsemeat with analogous incidents in the field of food safety. The Official Controls Regulation (EU) 625/2014 is very clear in addressing the requirements for effective methods and techniques for verification and the training of Authorised Officers of Food Law; however, compared to other areas of Official Controls, this fundamental activity has shown a lack of development and lack of innovation. This is particularly the case within the field of food fraud. A verification ecosystem built upon the principles of triangulating objective evidence will require more effective methods and techniques to be employed than traditional auditing and inspecting activities.

4.6 | Approaches to developing food fraud prevention strategies

The development of regulatory food fraud prevention strategies is in its infancy compared to financial fraud prevention strategies (Spink, 2019). Nonfood sectors suggest that for fraud prevention strategies to be effective, they need to combine governance practices, as well as mitigation and monitoring programs (Dianita et al., 2021); share information and embed education programs (Burke et al., 2022; Suh & Shim, 2020); and not just focus on detection approaches alone (DeZoort & Harrison, 2018). Braden (2014) argues that effective fraud prevention strategies require the establishment of a surveillance and fraud alert system, strict enforcement of fraud regulations, strong interagency cooperation, and increased public awareness of fraud and personal vulnerabilities to fraud. A comprehensive food fraud prevention program must integrate public and private aspects such as regulatory systems, sampling and monitoring programs that support effective detection, and appropriate awareness training programs for FBOs (Tibola et al., 2018). Strong sanctions that neutralize potential economic gains of committing fraud together with whistleblowing protocols and stronger data sharing and data control systems are all important prevention strategies (Afrianto et al., 2020; Collart & Canales, 2022; Suh & Shim, 2020) as well as developing collaborative networks between academia, industry, and regulators (Cadieux et al., 2019; Gimonkar et al., 2021). There is no single intervention or single approach to developing food-related fraud prevention strategies; therefore, multi-intervention prevention and surveillance strategies are required (Barnard & O'Connor, 2017; Barrere et al., 2020; Brereton et al., 2016; Everstine et al., 2018; Fassam & Dani, 2017), which encompass both effective regulations and the development of public awareness programs—especially through the use of technology, for example, to digitally trace and authenticate food (Bitzios et al., 2017; Lee et al., 2022)—and early warning systems that identify inappropriate activities (Deisingh, 2005). Multi-intervention prevention strategies must include the strengthening of existing FCMS at FBO and supply chain levels, intelligence sharing, and surveillance and digitization of supply chain systems (Brereton et al., 2016), focusing on data granularity, transparency, traceability, and integrity of supply (Cawthorn & Mariani, 2017; Ehmke et al., 2019).

In reviewing and critiquing the development of food fraud prevention plans, seven sources were considered that propose food fraud prevention plans at the national or FBO level (Codex, 2022; Spink, 2019; Spink, Fortin et al., 2016; Spink, Moyer et al., 2016; Spink et al., 2016, 2017; Spink, Chen et al., 2019; Wiśniewska, 2015). The comparative review of the models is structured with four stages (see Figures 1–3):

- Stage 1. Defining the scope, basic terms, and screening hazards/threats;
- Stage 2. Conducting hazard or threat analysis/an FFVA and documenting;
- Stage 3. Undertaking risk ranking using either a matrix, a decision tree, or another tool; and
- Stage 4. Developing the FCMS through validation, implementation, and verification.

These stages and the evidence synthesized are now all critiqued in turn. The narrative across the approaches suggests that the FBOs already have, or will need to have, formalized FCMS in place.

4.6.1 | Stage 1. Defining the scope, basic terms, and screen hazards/threats

This is the initial scoping and screening phase in preparation for undertaking the activities in Stage 2. As Spink et al. (2017) highlight, this initial stage is to develop a common starting point for the FFVA (Stage 2). The multidisciplinary team needs to be drawn together and, in many instances, will include as a core group the HACCP team, as they have a broad range of skills, knowledge, and experience, as well as those involved in site security and business continuity planning (BSI, 2017; Codex, 2022; Wiśniewska, 2015). Some literature sources describe this group as a Food Fraud Task Force (Spink, 2019). Having a good baseline level of information requires the collation of a range of background contexts. This includes describing which generic product groups or individual products are currently produced and

Model	Food Fraud Initial Screening model (FBO level)	Food Fraud Prevention Strategy (FBO Level)	Food Fraud Prevention Strategy (national level)	Stages of food fraud prevention. (FBO level)	Food fraud prevention cycle (FBO level)	HACCP-DP
Source	Spink Fortin, et al. (2016)	Spink, Moyer, et al. (2016)	Spink et al. (2017)	Spink (2019)	Spink, Bedard et al. (2019); Spink, Chen et al. (2019)	Wiśniewska (2015); Codex (2022)
Stage 1 Define scope, basic terms and screen hazards/ threats	Food Fraud Initial Screening (FFIS) Matrix Variables Product or Group AND Market or Region **Step 1** define the scope and basic terms. **Step 2** Review incidents (databases) and suspicious activity **Step 3A** Conduct FFIS for health hazards. **Step 3B** Conduct FFIS for enterprise wide risks and financial impact.	Food Fraud Initial Screening (FFIS) Matrix Review phase. Organize team. Create Food Fraud Policy, Mission Statement, Draft Food Fraud Prevention Strategy/Plan Conduct FFIS Gather background information to inform FFVA	Developing a common starting point and the developing and sharing of best practices for vulnerability assessments. Third parties develop standards and protocols so approaches can be audited and certificated.	**Gap Analysis** – ask seven questions. 1. FFVA undertaken (Y/N) 2. FFVA Documented (Y/N) 3. Food Fraud Prevention Strategy Implemented (Y/N) 4. FFPS Documented (Y/N) 5. Annual Food Fraud Incident Review completed (Y/N) 6. All types of Food Fraud addressed (Y/N) 7. All products from both incoming goods and finished goods through to the consumer. Addressed (Y/N) **Concept 1.** Develop and implement a food fraud policy statement. **Concept 2.** Create a FFPP Complete **seven steps** of implementing and managing food fraud prevention. **Step 1** Convene a Food Fraud Task Force **Step 2** Create an Enterprise-wide Food Fraud Policy/Mission Statement and begin drafting a Food Fraud Prevention Strategy/Plan **Step 3.** Conduct the pre-filter Food Fraud Initial Screening (FFIS).	**Step 1.** Consider new information through 1A. Review specific food fraud incidents internally or externally. 1B. Scanning. Consider broad changes e.g. market changes. 1C. Public Policy. Consider policy and regulatory changes. **Step 2.** Fraud Opportunity. 2A Consider guardians and hurdles. 2B. Consider victim. 2C. Consider fraudster. **Step 3.** Undertake vulnerability assessment. 3A. Initial screening.	**Step 1.** Assemble HACCP Team and Identify Scope Step 2. Describe product. **Step 3.** Identify intended use and users (especially vulnerable groups) **Step 4.** Construct flow diagram. **Step 5.** On-site confirmation of flow diagram **Step 6 (part).** List all potential hazards that are likely to occur.

FIGURE 1 Food fraud prevention strategies: Stage 1 (adapted from Onarinde et al., 2023).

Model	Food Fraud Initial Screening model (FBO level)	Food Fraud Prevention Strategy (FBO Level)	Food Fraud Prevention Strategy (national level)	Stages of food fraud prevention. (FBO level)	Food fraud prevention cycle (FBO level)	HACCP-DP
Source	Spink Fortin, et al. (2016)	Spink, Moyer, et al. (2016)	Spink et al. (2017)	Spink (2019)	Spink, Bedard et al. (2019); Spink, Chen et al. (2019)	Wiśniewska (2015); Codex (2022)
Stage 2 Conduct hazard analysis/ vulnerability assessment and document	Undertake FFVA (Very High to Very Low) **Step 4** (paper states this is risk ranking)	Undertake FFVA	Undertake FFVA at national and business level	**Step 4.** Review additional needs including additional information or a more detailed FFVA.	**Step 3.** 3B. Undertake vulnerability assessment. 3B. Detailed vulnerability assessment.	**Step 6. (part).** Conduct a hazard analysis to identify the significant hazards (Principle 1)
Stage 3 Undertake risk ranking using matrix or decision tree or other tool.	Corporate Risk Map - plots FFIS risk assessments 5x5 Matrix Likelihood (Very High to Very Low) AND Impact (Very High to Very Low) **Step 4** In Spink et al., (2019) this changes to Likelihood and Consequences	Map food fraud vulnerabilities.	-	**Step 5**. Review specific food fraud vulnerabilities in an enterprise risk map (Enterprise Risk Management)	**Step 4.** Enterprise Risk Rank.	**Step 6. (part).** Conduct a hazard analysis to identify the significant hazards (Principle 1) Often likelihood and severity used.

FIGURE 2 Food fraud prevention strategies: Stages 2 and 3 (adapted from Onarinde et al., 2023).

Model	Food Fraud Initial Screening model (FBO level)	Food Fraud Prevention Strategy (FBO Level)	Food Fraud Prevention Strategy (national level)	Stages of food fraud prevention. (FBO level)	Food fraud prevention cycle (FBO level)	HACCP-DP
Source	Spink Fortin, et al. (2016)	Spink, Moyer, et al. (2016)	Spink et al. (2017)	Spink (2019)	Spink, Bedard et al. (2019); Spink, Chen et al. (2019)	Wiśniewska (2015); Codex (2022)
Stage 4 Development, validation, implementation and verification of a food control management system (FCMS)	Resource Allocation Decision Based on risk ranking	Consider countermeasures and control systems to address Very High and High vulnerabilities. Propose a Food Fraud Prevention Plan	Develop and implement appropriate countermeasures and control systems.	**Step 6.** Consider countermeasures and control systems to address the 'very high' and 'high' vulnerabilities. **Step 7.** Propose a Food Fraud Prevention Strategy including the calibration of the Food Fraud risks on the enterprise risk map.	**Step 5.** Rank **Step 6,** Countermeasures and control system. **Feedback loop** back into Step 1.	**Step 6. (part).** Consider any measures to control identified hazards (Principle 1). **Step 7.** Determine the Critical Control Points (CCPs) (Principle 2). **Step 8.** Establish validated critical limits for each CCP (Principle 3). **Step 9.** Establish a monitoring system for each CCP (Principle 4) **Step 10.** Establish corrective actions (Principle 5) **Step 11.** Validation of the HACCP Plan and verification procedures (Principle 6) **Step 12.** Establish documentation and record keeping (Principle 7) **Step x.** Training (Codex requirement but not described as a step). Step y. Food defense plan Determine CDPs in your process. Devise food defense mitigations. **Step z.** Implement, test, assess and maintain the defense mitigations.

FIGURE 3 Food fraud prevention strategies: Stage 4 (adapted from Onarinde et al., 2023).

sold and which will be considered, and potentially which markets or geographic regions need to be included in the scope (Spink, Fortin, et al., 2016). During the market analysis, it is important to consider not only past and present activities, but also future market changes, policy changes, and any regulatory changes that could influence vulnerability to fraud (Spink, Chen, et al., 2019). This activity will define the scope and basic terms for the development of food fraud prevention strategies.

Next, it is important to identify whether the organization has a food safety policy, has referred to food fraud in its organizational mission statement, and already has a food fraud prevention plan (Spink, 2019; Spink, Moyer, et al., 2016). If these documents are in place, the team needs to review and revise as needed or create new documents if required. The preparation phase also needs to consider guardians, hurdles, and the kinds of perpetrators who might commit fraud (Spink, Chen et al., 2019). The FBO needs to develop a list of current food safety guardians and food safety hurdles and then the additional roles (guardians) and measures (hurdles) that relate specifically to food fraud prevention and detection. Spink (2016) and Spink, Fortin et al. (2016) define the food fraud initial screening tool and the need to prioritize potential issues within a corporate risk matrix, as discussed in Stage 2.

4.6.2 | Stage 2. Conducting hazard or threat analysis or an FFVA and documenting these processes

FFVA evaluates the potential of a food system to be vulnerable to food fraud (Onarinde et al., 2023). The FFVA approach involves a number of aspects including, for a given scope, the identification, assessment, and ranking of relevant vulnerabilities, where they arise, and what mitigation strategies or control measures can be adopted to reduce the vulnerability. Barrere et al. (2020) outline the steps of undertaking an FFVA as follows:

1. Draw together the appropriate team with the necessary capabilities to conduct the assessment (Stage 1);
2. Assemble all the information required for the assessment (supplier information, specifications for ingredients, processing materials, products, packaging materials, suppliers, etc.);
3. Conduct the vulnerability assessment (Stages 2/3);
4. Develop, validate, and implement the appropriate mitigation plan (Stage 4); and
5. Develop the FCMS to effectively monitor, verify, review, and refine the vulnerability assessment and mitigation plan (Stage 4).

Source		Joint Nordic Food Fraud Threat Assessment for Food Fraud	Spink, Fortin et al. (2016) Spink, Chen et al. (2019)	Van Ruth et al. (2017)	Silvis et al. (2017)	van Ruth & de Pagter-de Witte, (2020)	Song et al. (2021)	Yang et al. (2019)
Number of measures		22		50	50	50	50	48
Model (matrix or diagram)		Two matrices 5 x 5 matrix for assessment of impact and probability 4 x 4 matrix for assessment of impact and probability in national threat assessments with unknown dimension.	5 x 5 Matrix	Radar diagram	Ribbons SSAFE tool	50 measures with ranking	Radar diagrams and ribbons	Adaption of SSAFE tool in radar diagrams and ribbons
Assessment criteria								
Impact and probability		Very high, high, moderate, low, very low National threat impact and probability (high, moderate, low, unknown) Financial impact; Societal impact	Very high, high, medium, low, very low Likelihood, consequences, and impact included.	High, medium, low	High, medium, low	High, medium, low	High, medium, low	High, medium, low
Control measures	Managerial measures/ prevention control measures	X		X	X	X	X	X
	Technical measures	X		X	X	X	X	X
Drivers and motivations	Financial motives/ economic drivers	X		X	X	X	X	X
	Culture and conduct/ culture and behaviors	X		X	X	X	X	X
Opportunities	Technical possibilities/ opportunities	X		X	X	X	X	X
	Opportunities in time and space	X		X	X	X	X	X

FIGURE 4 Food fraud vulnerability models (adapted from Onarinde et al., 2023).

Manning and Soon (2019) critiqued FFVA models in the context of the food fraud triangle (Cressy, 1953) with the elements of pressure, opportunity, rationalization, and the food fraud diamond (incentive, opportunity rationalization, and capability) as proposed by Wolfe and Hermanson (2004). FFVA is only one stage of the development of food fraud prevention strategies and food fraud prevention plans. Eight sources that propose the development approach to FFVA and food fraud prevention strategies have been compared and contrasted (Figure 4). These sources are the Joint Nordic Food Fraud Threat Assessment for Food Fraud, Silvis et al. (2017), Song et al. (2021), Spink, Fortin et al. (2016), Spink, Chen, et al. (2019), Van Ruth et al. (2017), van Ruth and de Pagter-de Witte (2020), and Yang et al. (2019). The FFVA models themselves used the schematic assessment and presentation of vulnerabilities based on the use of a matrix, a ribbon, and/or a radar diagram. The criteria utilized in the vulnerability assessments reflect aspects of the food diamond, beginning with hurdles that act as deterrents against rationalization or reduce the capability to commit fraud. These hurdles are defined as technical measures, managerial measures, and prevention control measures. Opportunities or possibilities for food fraud are distinguished as technical, time, and space; incentives (as economic drivers and financial motives); and motivation (as financial, culture, conduct, and behavior); additionally, two criteria are used to assist in vulnerability ranking: first, likelihood/probability, and second, severity/impact, either financial or societal (see Figure 4).

The aspects of the type of fraudster and its influence on the assessment decision and also the need to "think like a criminal" are not explicit in these vulnerability assessment models but need to be included within food fraud prevention strategies and in designing food fraud prevention plans. In this context, capability reflects the ability of a fraudster to instigate and undertake fraudulent activities (Kowalska et al., 2018), and the personal attributes of the fraudster that contribute to fraudulent behavior(s) need to be considered within the fraud prevention strategies (Kassem & Higson, 2012). In this regard, Dorminey et al. (2010) position that the fraud diamond is of value in considering the individual fraudster but not collusion or collective predatory behavior (Manning, 2024). Predators who focus on these types of opportunities are highly organized and have the capability to conceal their activities, that is, they are not particularly driven by situational pressure or rationalization (Dorminey et al., 2010; 2012). Thus, FFVA, based on situational pressure and rationalization, is unlikely to identify predators, whether they are individuals or organized crime groups, and their activities (Dorminey et al., 2012). Therefore, whether the potential instances of fraud are enterprise related, that is, situational, or not must be determined. At this stage, all vulnerabilities are of interest, along with any opportunities for new threats or perpetrators; therefore, FFVA must be relevant, real-time, and reactive to be effective (Manning & Soon, 2019).

4.6.3 | Stage 3. Undertaking risk ranking using either a matrix, a decision tree, or another tool

The ranking of risk can be undertaken through a range of mechanisms including the common tool, a 5×5 risk matrix with likelihood and severity from very low to very high,

and a multiplier-based scoring system (see Figure 2). Other work has used risk ranking in different ways to assess not only vulnerability but also ease of detection (Djekic et al., 2018). Manning and Soon (2019) critiqued the development of FFVA assessments and their efficacy noting the following concerns:

- The score obtained assumes linear, single-event associations, and prioritizing as a result may be imprecise, for example, two equivalent scores for a vulnerability could have very different outcomes if actualized;
- There is a risk of a lack of consistency in applying scores based on perceptions and unconscious bias within the team. A lack of technical know-how, appropriate data, and access to suitable databases, as well as high levels of uncertainty in the data available and biases due to sampling programs used to develop the dataset, will also limit the efficacy of FFVA; and
- There is a risk of over- or underpredicting based on the level of confidence the team has in its abilities and the information upon which they are making their decisions.

4.6.4 | Stage 4. Developing the FCMS through validation, implementation, and verification

In Stage 4, appropriate countermeasures within the FCMS need to be developed for the very high and high vulnerabilities. The countermeasures then need to be validated and implemented, and a monitoring and verification program needs to be developed. This stage then feeds back into Stage 1, as new or different products are developed, and through horizon scanning activities (BSI, 2017), new vulnerabilities emerge. The food fraud prevention plan not only needs to identify countermeasures but also supports the implementation of activities to ensure that the guardians, hurdles, and other countermeasures are in place and effective; that sufficient resources are being applied; that appropriate training programs are in place; and that the plan remains agile and resilient (Wiśniewska, 2015). The validation of the FCMS once designed is essential to ensure its efficacy before it is operationalized. Ineffective verification of FCMS is a concern that needs to be addressed (Alrobaish, 2023). Wiśniewska (2015) states that defense plans, and by inference food fraud prevention plans, need to be routinely tested through a number of mechanisms, including simulations, tabletop exercises, mock incidents and recalls, post-event reflection and evaluation, and testing of business continuity planning. Another key aspect of Stage 4 is the design of effective guardianship strategies both inside and outside the FBO and in a national food fraud prevention strategy across the national food system (Onarinde et al., 2023). FBOs can also minimize fraud risk by integrating within their FCMS effective upstream prevention strategies, from the organization back through all tiers of their suppliers (Onarinde et al., 2023). These strategies need to be both passive and reactive, and they should be linked to, where possible, early warning systems that signal potential illegal activities. In the event of a failure of the FCMS, revalidation and reverification of the food fraud prevention strategies and the food fraud prevention plan are essential (Oleo et al., 2024).

5 | CONCLUDING THOUGHTS

Food fraud is an ever-present threat that regulators, FBOs, and consumers need to be aware of, prevent where possible, and address by developing mitigation strategies to detect and reduce its negative consequences. This paper has undertaken a comprehensive review of the context of food fraud prevention strategies and the approaches to developing an effective FCMS that can operate at FBO, supply chain, and system levels. First-generation tools have been developed for FFVA and risk analysis and to support the development of comprehensive food fraud prevention strategies. These have been assessed and critiqued, but much of the application is currently at a single FBO level rather than strategically across whole supply chains or integrated to develop a national food fraud prevention strategy. The singular nature of assessment and the singular nature of FCMS verification are also systemic weaknesses, as shown by a number of fraud-related incidents such as the 2013 horsemeat incident.

All FBOs need to recognize their vulnerability to food-related fraud and ensure they are appropriately assessing risk and operationalizing prevention and detection strategies (Joenperä et al., 2022). However, the methods described here are time-consuming to implement and need to be regularly reviewed and updated to ensure they remain valid; additionally, FBOs need to assess risks in how they allocate resources for validation, monitoring, and verification effectively (Bouzembrak et al., 2024). Bouzembrak et al. (2024, p. 2) highlight multiple limitations of current approaches, including the rigidity of existing single assessment approaches when the fraud risk is highly dynamic, for example, changes in suppliers, products, or processes; the approaches are highly dependent on the expertise and knowledge of assessors and the availability of information to underpin their assessment, which could lead to unreliability; and different FBOs may apply assessment approaches differently, leading to inconsistent assessments where they cannot be readily compared.

The use of AI-based predictive methodologies such as Bayesian Networks (BNs) using existing datasets has also

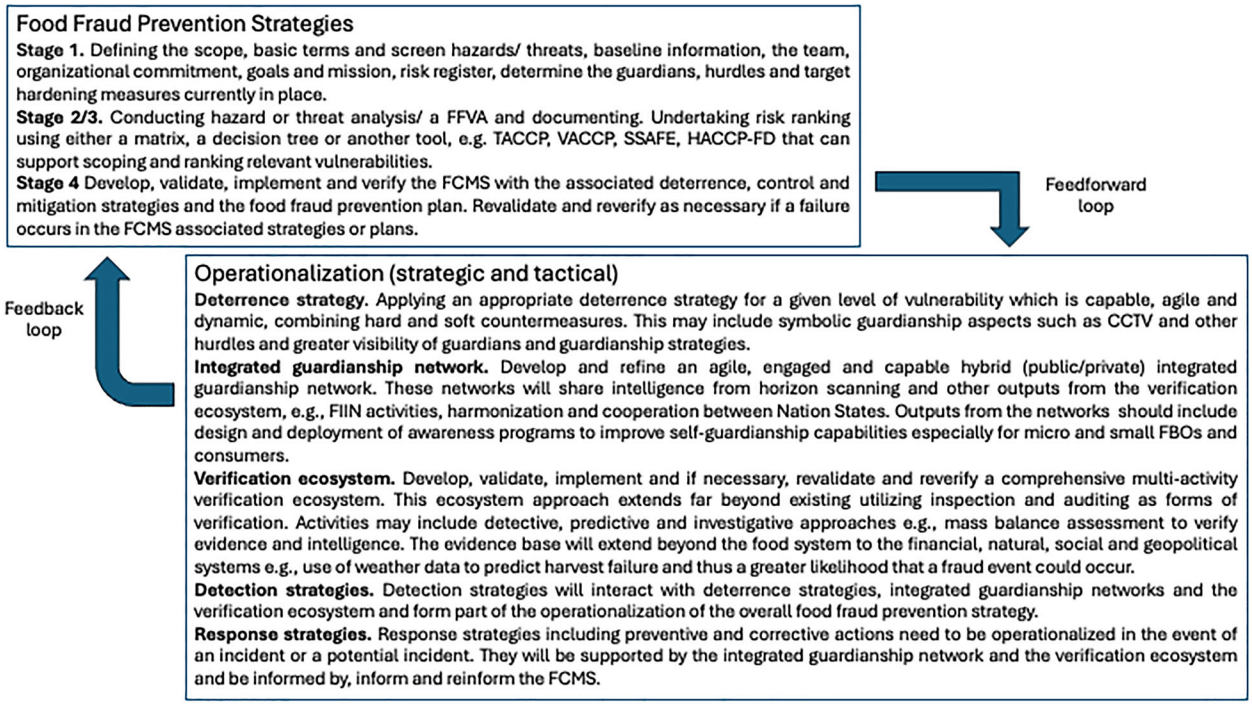

FIGURE 5 Food fraud prevention strategies, design, implementation, and operationalization.

been proposed as a means to support the development of food fraud prevention strategies. Using databases such as the EU Rapid Alert System for Food and Feed (RASFF), HorizonScan, Decernis, or MediSys, BN-based predictive methodologies can focus on the type of hazard and the timing of when fraudulent activities are most likely to occur (Bouzembrak et al., 2024; Gavai et al., 2023; Rezazade et al., 2022a, 2022b; Soon, 2020; Soon & Abdul Wahab, 2022), or they can utilize MediSys and the MediSys-FF tool (Bouzembrak et al., 2018; Marvin et al., 2022). However, Bouzembrak et al. (2024) argue that it is essential, when using predictive methodologies and specific databases to either hindcast, nowcast, and/or forecast, to be aware of the limitations of the dataset to predict the past (hindcasting), the present (nowcasting), or the future (forecasting), especially as hindcasting is of limited value when seeking to predict emergent forms of food fraud in the future. Backcasting can be used to determine how the desired future, in this case consistently safe, legal, and authentic food, can be achieved, then defining and planning follow-up activities and developing strategies, goals, and objectives that will lead to the achievement of the desired outcomes (Hardman, 2010; Quist et al., 2006). Backcasting, as an approach, allows for the consideration of complex issues where dominant biases are often part of the problem, and there is a need for change or the operational environment is subject to change (Quist et al., 2006). Backcasting describes "an overarching, multiphase process involving the cocreation of desirable future vision(s), followed by working back (or backcasting) from that future alternative to the present to design sequential steps for its achievement" (Davies & Doyle, 2015, p. 428). Backcasting has been proposed as an approach to develop technologies to reduce illegal fishing and fraudulent fish on the market (Willette et al., 2023), as well as more widely in terms of future-proofing and climate vulnerability. These approaches are worthy of future research.

There are some examples of national approaches explored in this paper, and examples were cited of integrated capable guardianship networks; however, these need to develop further, and the learnings from these networks need to be more widely available to micro and small businesses so they do not become fraud-related pinch points. Fraud vulnerability pinch points need to be assessed, and Soon, Manning, et al. (2019) proposed a food crime countermeasures framework that has been adapted in the context of this study (Figure 5) and graphically summarizes many of the themes in this paper.

This work has implications for policymakers, Official Controls bodies, the food industry, and ultimately consumers who seek to consistently produce, process, distribute, sell, oversee, and purchase food that is safe, legal, and authentic. This research contributes to both drawing together extant knowledge and activities and underpinning future research, regulatory and industry assessment approaches, and the operationalization of food fraud prevention strategies, effective and agile FCMS, integrated guardianship networks, and verification ecosystems.

AUTHOR CONTRIBUTIONS

Louise Manning: Methodology; validation; formal analysis; writing—original draft; writing—review and editing; investigation. **Andrew MacLeod**: Conceptualization; methodology; investigation; validation; writing—review and editing; formal analysis. **Christian James**: Conceptualization; validation; investigation; writing—review and editing; formal analysis. **Mathew Thompson**: Conceptualization; investigation; writing—review and editing; formal analysis. **Samson Oyeyinka**: Conceptualization; methodology; investigation; writing—review and editing; formal analysis. **Nick Cowen**: Investigation; writing—review and editing; formal analysis. **Joshua Skoczylis**: Investigation; writing—review and editing; formal analysis. **Bukola A. Onarinde**: Conceptualization; methodology; data curation; investigation; validation; formal analysis; supervision; funding acquisition; visualization; project administration; resources; writing—review and editing.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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