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FOOD SUPPLY CHAIN VULNERABILITY: A REVIEW OF EMERGING CHALLENGES AND RESPONSES

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ABSTRACT
Purpose: Increasing globalisation and pressures to reduce costs and improve efficiencies have increased food supply chain complexity. This has given rise to conditions that increase food firm vulnerability to both food fraud (for economic gain) and attack (for psychological or ideological reasons), (van Ruth, *et al*. 2017; Spink *et al*., 2017). Thus it is timely to review food defence initiatives across a number of countries to determine the feasibility of incorporating specific food defence measures in supply chain risk management systems.

Design/methodology/approach: Due the emergent nature of the challenges associated with food defence grey as well as academic literature were reviewed. Based on an initial scan of the literature (academic, grey and open) specific search terms and keywords, key authors, key institutions (e.g. European Food Safety Authority (EFSA), FDA, WHO) and key publications were identified. Terminology used was also scanned across social media platforms (in particular Twitter). This informed the key words used in a systematic review of literature using the following databases Google Scholar, Science Direct, Web of Science, EBSCO (business complete) and Scopus and the searches were extended to non-peer-reviewed publications. The "grey" literature included publications by companies involved in food safety training, industry magazines, white papers, publications of standards groups such as GFSI, SSAFE, GMA and the BRC, regulatory authorities and online blogs and websites.

Findings: The development of food supply chain defence initiatives is at an early stage and represents an area of on-going activity and trial. A review of such initiatives identifies key strategies (deterrence; detection; control and countermeasures), increased and ongoing effort to develop rapid tests, and vulnerability assessment tools developed within a regulatory framework. This review points to the need for ongoing development of food supply chain actor capacity to use vulnerability tools and associated databases and to embed fraud/threat defences into their management processes.

Value: A number of factors combine to increase the challenges posed by food fraud and attack in this decade. This study aims to contribute to emerging research by exploring the context, considering key characteristics of food fraud/attack and evaluating responses by companies and regulatory authorities, in the context of resilient supply chains. As such it may be of interest to researchers, policy makers and food supply chain actors.

Research limitations/implications: This paper is limited to the review stage of a larger research project.

Practical implications: In addition to providing an evidence base to underpin the development of a more food resilient food supply chains, this study aims to raise awareness and knowledge about the challenges posed by fraud/attack.

INTRODUCTION
Increasing globalisation and pressures to reduce costs and improve efficiencies have increased food supply chain complexity. This has given rise to conditions that increase food

firms' vulnerability to adulteration of products through both fraud (for economic gain) and threat (for psychological or ideological reasons), (Moyer et al., 2017; van Ruth et al., 2017). Adulteration is the deliberate addition of, or alteration to, an ingredient in a food product for malicious reasons (Moyer et al., 2017). Thus, the concept of adulteration implicitly involves the question of the actor's intention and motivations. By contrast, contamination – which is the focus of Food Safety and Food Quality - is accidental and may not involve deliberate actions by any human or organisational actor in the production network or chain. Researchers, policy makers and supply chain stakeholders have distinguished between two categories of motivations for adulteration (GFSI, 2014); economically-motivated adulteration; and ideologically-motivated adulteration. Responses to prevent, deter, detect, or mitigate the effects of these two categories of motivation have been correspondingly named "Food Fraud" and "Food Defence" (or "Food Threats"). These concepts extend beyond Food Safety and Food Quality, which are concerned with unintentional actions that endanger or contaminate the food supply, because food fraud and food threat are the result of intentional action on the part of malevolent or criminal actors (see Figure 1).

Based on a systematic review of literature in the field, this paper aims to establish conditions contributing to the emergence of these challenges, current responses to these threats and the underlying assumptions, principles and processes. The paper is structured as follows: (i) the next section defines and describes both food fraud and food defence, (ii) this is followed by a methodology section that outlines the systematic literature approach adopted, (iii) the findings of this review are reported in the following section and (iv) the paper concludes with a discussion of these findings and puts forward suggestions for future work.

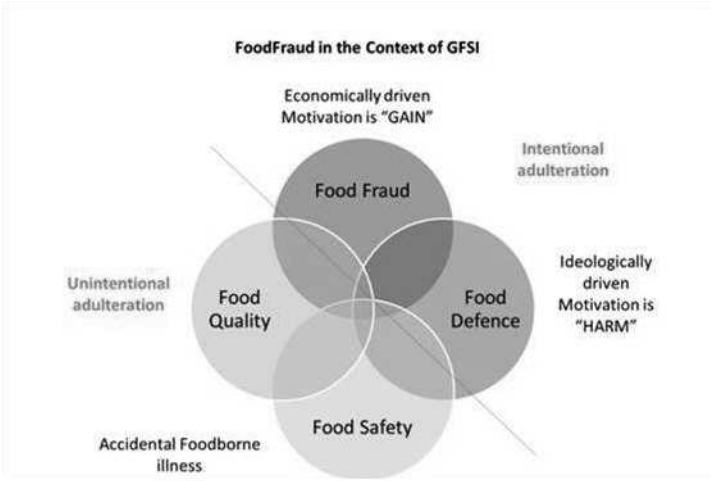


Figure 1 Food Fraud - adapted from GFSI (2014)

DEFINITIONS – Food Fraud and Food Defence

Food Fraud encompasses a wide variety of intentional actions, motivated in one way or another by the potential for economic gain, or – less frequently perhaps - to avoid economic loss. Thus, most cases of food fraud involve the substitution of a relatively expensive ingredient with a less expensive one at some point in the supply chain, and consequent monetary gain for that intermediary supplier. In some other cases an ingredient that was temporarily unavailable or in short stock may be substituted because the processor wished to satisfy a contract or to maintain an established supply relationship. We may also distinguish between two categories of food fraud, which have been termed "intrinsic" and "extrinsic" (Manning, 2016; Manning and Soon, 2016), although not all cases can be clearly categorised as one or the other. Intrinsic frauds involve the material substitution of an ingredient – for example "filling" dried oregano herbs with olive or myrtle leaves (Black et al., 2016). Extrinsic frauds, by contrast, are those that misrepresent "extrinsic" properties of an ingredient, for example whether it is of organically-certified origin (Megget, 2018), has PGI/PDO certification (Marks and Paravicini, 2017); or is produced in conformance with special rules and conditions, such as being halal (McElwee et al., 2017). Many extrinsic frauds are also classified as being cases of mislabelling – this was the most frequently reported classification in the EU Food and Feed Alerts (RASFF) database in 2017. EMA (Economically Motivated Adulteration) has emerged as a term to cover not just deliberate adulteration but also misrepresentation of foods for economic gain and thus covers a range of fraud activities.

Food Threats – and the response to these, termed "Food Defence[1]"- are cases of adulteration that are motivated by ideological, political, or personal factors. These range from large-scale adulteration for ideological/political reasons – sometimes termed "bio-terrorism", or "agro-terrorism" – to those arising from much more local reasons of personal animus or enmity, most typically actions by a disgruntled employee aimed at damaging the economic or reputational position of their employer. While much attention and research, especially in the USA, has focussed on the first type of food threat (Mitenius et al., 2014), documented incidents of that kind have been extremely rare, with the most prominent being the Oregon salad-bar attacks in 1984 which were motivated by political conflicts at the local-government level (Török et al., 1997). By contrast, the second type, arising from personal grievances, have been quite common and widely reported across different industry sectors and geographic regions (Mitenius et al., 2014).

METHODOLOGY – Systematic Literature Review

For this review we followed the general approach of Briner and Denyer (2012). However, we retained the general topics of Food Fraud and Food Threats, rather than refining them to a specific research question, as those authors advocate. The reasoning for that decision was that these topics are currently under-researched and consequently knowledge is too unstructured for specification of questions to be feasible or productive. In addition, we wanted to review a wide range of research questions related to these topics covering descriptive accounts of incidents, theories on motivations and strategies, and practices (both extant and proposed) for managing the risks resulting from food fraud and threats. With that one exception we followed the steps specified in Briner and Denyer's method as illustrated in Figure 1**Error! Reference source not found.**.

The set of search terms used are listed in **Error! Reference source not found.**. These terms were chosen based on initial scanning of the literature, and also because they were "statistically unlikely phrases". Searches were made in multiple databases: Science Direct, Web of Science, Scopus, EBSCO[2], and AgEconSearch. The results of these searches are shown also in **Error! Reference source not found.**.

Initial selection screened for relevance, e.g. excluding articles on the details or refinement of analytical techniques. Secondary selection involved first merging references and removing duplicates. The next step involved retaining only those articles with non-zero citation counts, based on Google Scholar data. Finally, the uncited articles were reviewed for quality and those which the authors judged to be authoritative (e.g. published by a competent authority or noted author), topical, or otherwise novel were retained.

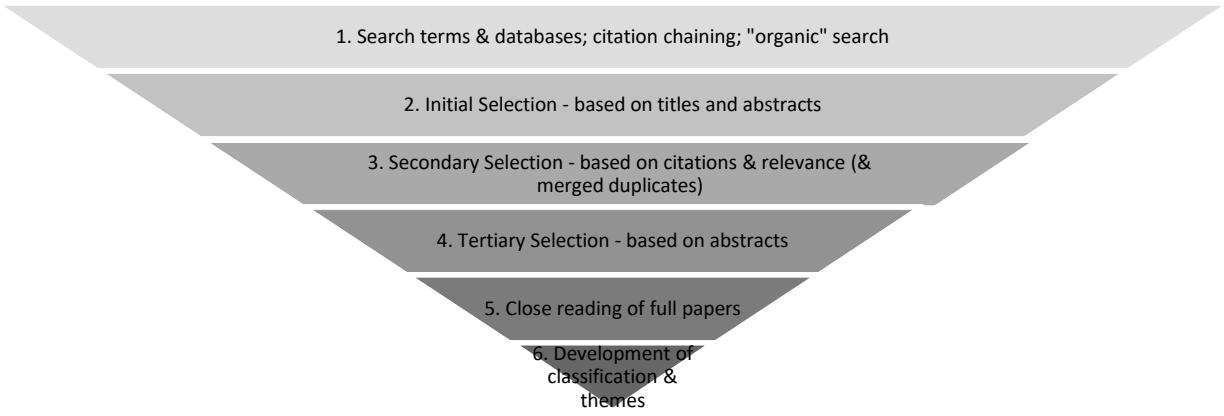


Figure 1 Search & Selection Process

[1] We use the UK spelling, although most of the literature on Food Defence/Defense originates in the USA.

[2] For EBSCO we choose to search the following sub-collections: Academic Search Complete Business Abstracts, Business Source Complete, eBook Collection, Readers' Guide, Regional Business News, Social Sciences Full Text, SocIndex, UK & Ireland Reference Centre.

Subsequent to selection a number of practices advocated by Briner and Denyer were used to expand the set of resources and to increase its comprehensiveness. These included "citation chaining", working forward from the most cited papers to identify newer citing articles; and working backwards from the references of the most-cited articles. Explicit searches were also made for additional items, e.g. in the forms of presentations and reports by the most-cited authors, and in the archives for those journals with the most articles in the original corpus. Finally, as this is an emerging area of interest, the "grey" literature was deemed important (Adams et al., 2017). Additional articles were collected through what could be termed "organic search", for example ones recommended by experts and colleagues, ones publicised on social media (Twitter) by a list of authorities that had been compiled, and finally by searching the web-sites of organisations known to be actively working on the topic, such as GFSI, BRC and SSAFE. At the end of this stage 509 items were retained, categorised as follows: 304 cited articles; 118 uncited but relevant; 87 'organic' (incl. grey literature).

Table 1 Search terms & statistics

Search Terms	**Science Direct**	**Scopus**	**Web of Science**	**EBSCO***	**AgEcon Search**
food AND fraud	8577	6442	8542	4729	18
"food fraud"	347	594	179	431	0
"food Defence"	173	352	79	140	8
"food defence"	42		15	11	1
"food threat"	19	27	4	22	0
"economically motivated adulteration"	117	377	64	52	0
"supply chain resilience" AND food	45	208	8	8	0
"supply chain vulnerability" AND food	41	177	5	8	0
"vulnerability resolution initiative"	0	0	0	0	0
TOTAL	784	1735	354	672	9

Tertiary selection involved review of the full metadata for the 509 articles and reading of the associated abstracts. In this stage selection was again based on relevance (e.g. excluding consumer studies, and papers on methods for predictive modelling), timeliness (noted but deleted historic/archival articles), appropriateness (e.g. supply chain risk management/resilience), and quality (e.g. short commentaries). In addition, the process of developing themes to summarise this body of research knowledge was begun at this stage. At the end of tertiary selection 180 articles were retained, which were then divided out among the research team for close reading and for analysis using the initially developed set of themes. The output of the final (close-reading) stage was, (i) a set of themes and (ii) thematic assignment of the corpus of articles.

FINDINGS

Motivation – rational behaviour (for a criminal mind)

From a motivational perspective fraud/threat differs fundamentally from food safety and quality. Most authorities on food fraud/threats, e.g. Spink et al. (2013, 2016, 2017) in relation to fraud and the WHO (2002) on defence, have argued that these activities differ markedly from the type of issues that are familiar to producers in relation to Food Safety. They argue that in food safety one seeks to control frequently occurring events, that arise from natural sources such as contamination or processing errors, and therefore the focus of controls is in identifying the most important (or critical) risks, and then initiating responses that reduce the likelihood and consequences of those risks. HACCP (Hazard Analysis and Critical Control Points) is the primary example of such an approach. Risks and likelihoods of this kind are identifiable, enumerable, and quantifiable because, they are internal to the processing unit and, being frequently occurring, are amenable to data collection on their context, causes and overall likelihood. By contrast, in the case of fraud/threat vulnerabilities may have never occurred before, may never occur again, or

may be a potential opportunity that never leads to an actual event. It is such vulnerabilities –"weakness[es] or flaw[s] that create[s] opportunities for undesirable events" (Spink et al., 2017:216)– that matter when developing countermeasures against fraud or threats, and these vulnerabilities can be assessed only qualitatively in terms of likelihood and consequences, i.e. "the susceptibility of the system" (Spink et al., 2017:216). Some aspects of a vulnerability assessment may of course be aided by quantitative data sources (e.g. commodity prices movements) and it is suggested that these are incorporated in response strategies (FSA and NSF, 2015).
Spink et al. (2017:216) further argued that the management of fraud (and, by extension, of threats) "necessitates a shift of the focus of countermeasures and control systems from intervention and response [i.e. mitigation] to prevention". Here, he defines (from ISO standards) "mitigation" as "countermeasures … to reduce the consequence of the event", where those events arise from "risks that cannot be eliminated" (Spink et al., 2017:217). He defines as countermeasures "intended to reduce or eliminate the likelihood of the event occurring", and thus prevention "focuses on identifying and eliminating or reducing vulnerability". In summary, therefore, the argument made in the research on Food Fraud and Food Threats is that countermeasures against these risks should be based on prevention of the causes of such events, i.e. by assessing vulnerabilities; whereas countermeasures in the field of Food Safety are based on mitigating the consequences of risks to safety of the product, by assessing risks especially at critical points in the production process (Spink et al., 2017:217).

Response – think like a criminal

Given this motivation, responses focus attention on the conditions that lead to fraud/threats, with assessment tools designed to address motivations and opportunities to commit such offenses and responses are designed to detect and respond to them (Manning and Soon, 2016; van Ruth et al., 2017). Thus, in very broad terms, these responses can be described as strategies based on:

- Deterrence;
- Detection;
- Control and Countermeasures.

These strategies seek to shift the balance from low risk of detection and good opportunity to profit illegally to high risk of detection and strongly negative consequences of such for the perpetrator. The food fraudster's attention is focused on market signals such as price-spikes or increasing demand for a commodity and the potential opportunity to act which is dependent on issues such as complexity of supply chain or availability of technology and knowledge to adulterate, and thus they seek to identify areas where the chances of detection and/or consequences if detected are low. Thus strategies to combat this seek to enhance horizon scanning to detect candidate products/ingredients and improve visibility and information sharing. Similarly, terrorists are attracted to opportunities to act where they have impact. On the other hand, they may be less concerned with detection after the event, but are concerned about surveillance while planning. Thus, strategies to respond are also informed by horizon scanning, visibility and information flow.

Vulnerability – identifying weak points

Although other states and regions are developing law in relation to fraud and threat (Mol, 2014; Walker, 2017; Zhang and Xue, 2016), almost all of the extant research is concerned with the US or the EU. In the US, the overarching piece of law concerning fraud and threat is the Food Safety Modernization Act (FSMA), signed into law in 2011. This is considered to be the most significant reform of Food law in the US since 1938 (Layton, 2009). In particular, in its provisions on "Preventive Controls", it addresses "preventing intentional adulteration from acts intended to cause wide-scale harm to public health, including acts of terrorism targeting the food supply". While the main focus of the law is on food threats, it now incorporates requirements for similar preventive strategies against economically-motivated adulteration (food fraud). Specifically, it requires vulnerability assessments against food fraud: events that could lead to a "hazard that requires a preventive control" from an act that is "economically motivated" (Spink and Moyer, 2017:58).

In the EU the central law is Regulation (EU) 2017/625, which updates the earlier Regulation (EC) 178/2002. The 2002 regulation established the European Food Safety Authority (EFSA) and placed the HACCP process at the centre of food safety practice. The 2017 regulation, developed in the wake of the horse meat fraud (Elliott, 2014) added provisions against what it termed "fraudulent or deceptive practices along the agri-food chain" and required the relevant national authorities to take account of "potential risks and the likelihood" of such events occurring. In addition, it encouraged the development of cross-national information sharing, which have subsequently been implemented through mechanisms such as RASFF and European Food Fraud Network (EFFN).

In response to this a range of industry standards have been developed or adapted (given the limitations of established food quality assurance process (e.g. HACCP) to equip food supply chain actors to respond to these challenges). Such standards specify processes and tests that food business operators and auditors can use in practice to identify and resolve fraud- or threat-related - vulnerabilities in their production systems. Over the past two decades private organisations (e.g. BRC, SQF) have developed internationally accepted quality assurance standards. These standards, which usually seek accreditation from established global bodies (e.g. ISO, GFSI), require certified food supply chain actors to employ various processes and methods which in turn are audited. In recent years the processes required (e.g. HACCP) have been adapted to include measures that respond to food fraud and treats. While these measures in turn differ somewhat they all include a vulnerability assessment tool that assesses level of opportunity and motivation and adequacy of control measures. These tools are largely self-assessment with links to databases (e.g. commodity prices, fraud/threat incidents such as USP and RASFF) to support horizon scanning. Figure 2 illustrates the role and relationship between accreditation and certification within the overall international and national legal context.

In response of the proliferation of schemes at the Certification level in relation to food safety, and the consequent burden of regulation and auditing on businesses (Kleboth et al., 2016), efforts were initiated by industry actors to create more loosely-specified and more encompassing schemes, that would accredit the various "Standards" developed and promoted by the Certification bodies. Most prominent among these are the Global Food Safety Initiative (GFSI), established in 2000, under the auspices of the Consumer Goods Forum (CGF, then CIES), a group comprising of major international food manufacturers and retailers. One of this initiative's major goals was to reduce redundancy of audits, so that a producer could be "certified once, accepted everywhere" (van der Meulen, 2011:116). A second accreditation body is the International Standard Organisation (ISO), which developed a food safety standard ISO 22000, supported by the multi-national food producers, i.e. the "big brand holders" (van der Meulen, 2011:132). However, the retailers were slow to accept and adopt ISO 22000, and so a new organisation was established, the Foundation for Food Safety Certification (FSSC) and this organisation developed a broader standard, FSSC 22000[3], issued first in 2009. FSSC 22000 is among the standards accepted by GFSI. Thus GFSI has emerged as the dominant accreditation body. These standards, classified as 'private law' (van der Meulen, 2011), are based on a general "prevention and vulnerability reduction approach" (van Ruth et al., 2017:70) with a vulnerability assessment tool fundamental to their operation.

[3] FSSC 22000 integrated ISO 22000, and additional module that was called PAS 220, issued first in 2008.

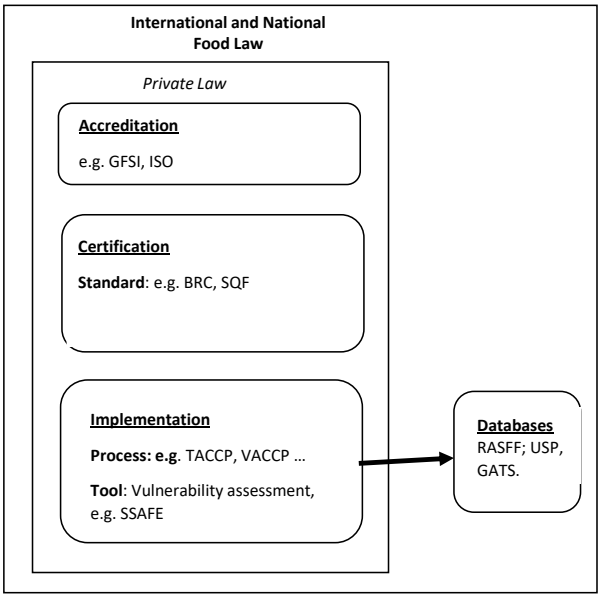


Figure 2 Accreditation and Certification Bodies

DISCUSSION AND CONCLUSIONS

Some key themes arise from this review: susceptibility, role of law and standards, and information flow. Food system susceptibility arises due to weakness/gaps that are identified and exploited by perpetrators intent on fraud/threat rather than vulnerability that we typically consider in the field of supply chain management, i.e. risk level and capability to respond. Hence response to fraud/threat focusses on weakness or gaps within the system, with an emphasis on prevention, rather than mitigation. The role of information flow is crucial to response strategies with a fundamental need for collaboration among food system stakeholders at various levels. Database development has been facilitated by both public agencies (e.g. EFFN in EU) and commercial concerns such as USP, based in the US, and FERA (horizon scanning) in the UK. An increased and ongoing effort to develop rapid testing methods (Ellis et al., 2015) has greatly enhanced surveillance of fraud/threat. This review points to the need for ongoing development of food supply chain actor capacity to use databases and embed fraud/threat defences into their management processes.

As evident from above, quality control and assurance processes fall short when dealing with fraud/threats, as suppliers intentionally set out to act opportunistically in their own self-interest and to the detriment of the buyer. For example, imposition of contractual penalties or reputational loss are not adequate penalties to deter those of a criminal or terrorist mind-set, rather legal frameworks can play a role. Indeed, deterrence as a strategy to control fraud and threat relies primarily on the State, by relying on it for "enforcing policies and regulations" (A. T. Kearney and GMA, 2010:19). Furthermore, the public nature of such prosecutions creates a less attractive environment for perpetrators, as does a visible response by supplier chain actors through use of risk assessment tools usually linked to industry level standards and associated processes. Activity to date also points to a role for 'private law' (i.e. industry imposed standards), since certification is a requirement for doing business in many contracts the non-conformant business is effectively excluded from such business relationships and may be forced to accept lower prices or more disadvantageous conditions. A non-conformant business consequently is positioned outside of, and excluded from doing business with, the whole group of conformant businesses. It is likely that the effectiveness of this will vary with the type of perpetrator, with a negative impact on suppliers seeking to 'cut corners' opportunistically and little impact on 'professional' criminals. While there has been reference to 'organised crime', many perpetrators may well be classified as 'rogue traders' rather than participants in 'organised crime' or, at the other end of the spectrum suppliers seeking to 'cut corners' opportunistically. Thus further research that classifies and measures the impact of different types of perpetrators is warranted. Moreover, large businesses, for example the large

multi-national food processors or retail chains that are the sponsors or members of the GMA (Grocery Manufacturers Association) or GFSI, can, by specifying conformance to their standards (which now include food fraud/threat defences), exert an influence that supports deterrence throughout the food supply chain.

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